IRC:5-2024

# STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR ROAD BRIDGES

## SECTION-I
## GENERAL FEATURES OF DESIGN
*(NINTH REVISION)*

INDIAN ROADS CONGRESS
2024

# STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR ROAD BRIDGES

## SECTION-I
## GENERAL FEATURES OF DESIGN
## *(NINTH REVISION)*

***Published by:***

**INDIAN ROADS CONGRESS**

Kama Koti Marg,
Sector-6, R.K.Puram,
New Delhi-110022
June, 2024

Price : ₹ 800/-
*(Plus Packing & Postage)*

# STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR ROAD BRIDGES

## SECTION-I
## GENERAL FEATURES OF DESIGN

*(NINTH REVISION)*

**Authors' Name**

Indian Roads Congress

**Published by**

Indian Roads Congress

**Publisher's Address**

Kama Koti Marg, Sector-6, R.K. Puram, New Delhi-110022

**Printer's Details**

P.P. Enterprises, New Delhi – 110055

**Edition Details**

First Published: January, 1956
Second Revision: October, 1960
Third Revision: September, 1964
Fourth Revision: September, 1966
Fifth Revision: December, 1970
Sixth Revision: April, 1985
Seventh Revision: December, 1998
Eighth Revision: June, 2015
Ninth Revision: June, 2024

**Disclaimer:** Indian Roads Congress is a professional body which formulates codes and guidelines for the guidance of Engineers and professionals in the "Roads" sector. These codes and manuals are not a substitute to the application of Engineering mind / Engineering sense. All the Engineering Organizations are hereby enjoined to take conscious decisions in the light of IRC Codes / Manuals based on Engineering principles and Engineering logic in the best interest of the road users.

*(All Right Reserved. No part of this publication shall be reproduced, translated or transmitted in any form or by any means without the permission of the Indian Roads Congress)*

(510 Copies)

# CONTENTS


| S. No. | Description | Page No. |
|---|---|---|
| **Personnel of the Bridge Specifications and Standards Committee (BSS)** | | i - ii |
| | Introduction | 1 |
| 100 | Scope | 3 |
| 101 | Definitions | 3 |
| 102 | Classification | 9 |
| 103 | General Provisions | 11 |
| 104 | Planning Considerations | 13 |
| 105 | Geometric Design Considerations | 19 |
| 106 | Hydrology and Hydraulic Design | 22 |
| 107 | General Design Requirements | 32 |
| 108 | Construction & Constructability Considerations | 33 |
| 109 | Auxiliary Components | 37 |
| 110 | Illumination | 43 |
| 111 | Road Signs and Signals | 44 |
| 112 | Aesthetics | 45 |
| 113 | Operation & Maintenance | 48 |
| **Appendices:** | | |
| | Appendix - 1 | 49 |
| | Appendix - 1(a) | 51 |
| | Appendix - 2 | 52 |

# PERSONNEL OF THE BRIDGES SPECIFICATIONS AND STANDARDS COMMITTEE (BSS)

**(as on 18th November, 2023)**

| | | |
|---|---|---|
| 1 | Prasad, P.V.V.S.S. Ravi (Convenor) | Director General (Road Development) & Special Secretary to Govt. of India, Ministry of Road Transport & Highways, New Delhi |
| 2 | Sinha, B.K. (Co-Convenor) | Additional Director General, Ministry of Road Transport & Highways, New Delhi |
| 3 | Shrivastava, O.P. (Member-Secretary) | Chief Engineer (S&R) Ministry of Road Transport and Highways, New Delhi |

***Members***

| | | |
|---|---|---|
| 4 | Balakrishna, Y. | Additional Director General, Ministry of Road Transport & Highways, New Delhi |
| 5 | Banerjee A.K. | Member (Retd), National Highway Authority of India |
| 6 | Basa, Ashok | Managing Director, CEM Engg. & Cons. (P) Ltd. |
| 7 | Dhiman, R.K., VSM | Chief Engineer (RBAT), Border Roads Organization |
| 8 | Gairola, Col. Pradeep | General Manager, NHIDCL |
| 9 | Garg, Sanjay | Chief Engineer, Ministry of Road Transport & Highways, New Delhi |
| 10 | Ghoshal, Amitabh | Chief Advisor to Board, STUP (Retd.) |
| 11 | Goel, Dr. Rajeev | HOD Bridge Division, CSIR-CRRI, New Delhi |
| 12 | Heggade, V.N. | Former CEO of STUP & Former Executive Director of Gammon |
| 13 | Jaigopal, R.K. | Managing Director, Struct Geotech Research Laboratories (P) Ltd., Bengaluru |
| 14 | Jayachandran, Dr. Arul | Indian Institute of Technology, Chennai |
| 15 | Joshi, C.P. | OSD & IE, MSRDC Ltd. |
| 16 | Kumar, Dr. Ramancharla Pradeep | Indian Institute of Technology, Hyderabad |
| 17 | Kumar, Manoj | Member (Project), National Highways Authority of India |
| 18 | Kumar, Vikas | Managing Director, Delhi Metro Rail Corporation |
| 19 | Laskar, Prof. Aminul Islam | National Institute of Technology, Silchar |
| 20 | Meghwal, D.R. | Chief Engineer, NH & PP, PWD Rajasthan |
| 21 | Nirmal, S.K. | DG (RD) & SS (Retd.), MoRTH & Secretary General, IRC |
| 22 | Panday, I.K. | DG (RD) & SS (Retd.), Ministry of Road Transport and Highways, New Delhi |
| 23 | Pawar, Yogesh | Managing Director, UPSBC, Lucknow |
| 24 | Puri, S.K. | DG (RD) & SS (Retd.), Ministry of Road Transport and Highways, New Delhi |
| 25 | Rastogi, D.K. | Chief Engineer (Retd.), Ministry of Road Transport and Highways, New Delhi |

| | | |
|---|---|---|
| 26 | Roy, Dr. B.C. | Managing Director, RUPL & RUICP |
| 27 | Salunkhe, Sadashiv S. | Secretary, PWD Maharashtra |
| 28 | Shankarlingam, C. | Adviser, L&T Limited, Chennai |
| 29 | Sharan, G. | DG (RD) & SS (Retd.), Ministry of Road Transport and Highways, New Delhi |
| 30 | Sharma, R.S. | Managing Director, M/s Sugam Tech, New Delhi |
| 31 | Shivakumar, B.S. | Chief Engineer, KRDCL, Karnataka |
| 32 | Singh, P.P. | Director (CB5), RDSO |
| 33 | Singh, Ranjit | Additional Director General, (Border) Central Public Works Department |
| 34 | Singh, Sanjay Kumar | Managing Director, BRPNL, Patna |
| 35 | Singla S.P. | Managing Director, M/s SP Singla Constructions Pvt. Ltd. |
| 36 | Sinha, N.K. | DG (RD) & SS (Retd), Ministry of Road Transport and Highways |
| 37 | Sinha, Prof. Ravi | Indian Institute of Technology, Mumbai |
| 38 | Tandon, Prof. Mahesh | Managing Director, Tandon Consultancy Pvt. Ltd. |
| 39 | Walia, Lt. Gen. Arvind | Engineer-in-Chief, MES |
| 40 | Yadav, D.K. | Engineer-in-Chief, PWD Uttarakhand |

### *Corresponding Members*

| | | |
|---|---|---|
| 1 | Bhowmick, Alok | Managing Director, M/s BSEC Noida |
| 2 | Subbarao, Dr. Harshavardhan | Chief Managing Director, M/s Construma Consultancy Pvt. Ltd. |
| 3 | Tambe, S.R. | Secretary (Retd.), PWD Maharashtra |
| 4 | Upadhyay, Prof. Akhil | Indian Institute of Technology, Roorkee |
| 5 | Verma, G.L. | Managing Director, EPC |

### *Ex-Officio Members*

| | | |
|---|---|---|
| 1 | President, Indian Roads Congress | (Vasava, Sandeep B.) Housing Commissioner, Gujarat Housing Board, Govt. of Gujarat |
| 2 | Director General (RD) & Special Secretary to Govt. of India | (Prasad, P.V.V.S.S. Ravi) Ministry of Road Transport & Highways, New Delhi |
| 3 | Secretary General, Indian Roads Congress | (Nirmal, S.K.) |

# STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR ROAD BRIDGES

## SECTION-I
## GENERAL FEATURES OF DESIGN

### INTRODUCTION

The work of Ninth Revision of "Standard Specifications and Code of Practice for Road Bridges Section I - General Features of Design" was taken up by the General Design Features Committee (Bridge and Grade Separated Structures) (B-1) under the Convenorship of Shri N K Sinha during the later half of its tenure 2021-2023, as the work of revision of IRC:78 Standard Specifications and Code of Practice for Road Bridges Section VII Foundations and Sub Structure was completed by the B-3 Committee on Foundation, Sub-Structure Protective Works and Masonry Structures Committee in order to bring uniformity among the IRC Codes and to incorporate the latest trends in design and construction of road bridges

Accordingly, the work of revision of IRC 5 was entrusted to a Sub-group under the Convenorship of Shri Sanjay Garg and Late Shri Ashok Kumar, Shri H.C. Arora, Shri Ashok Basa, Shri R.S. Sharma, Dr. S. Suriya Prakash, Shri P.V. Mayur and Shri C. Sankaralingam, as members, which carried out the initial revision which was discussed in a number of meetings of B-1 Committee. Accordingly, the revised document was improvised in June 2023. However, the Convenor Shri Sanjay Garg resigned. The IRC B-1 Committee then appointed Shri Rajiv Ahuja as Convenor of the Sub-group to finalise the revision for submission to the B – 1 Committee. Also, Shri D K Rastogi was included as member in the Sub-group.

The draft revision of IRC 5 after having been discussed in a number of meetings was finally approved by the B-1 Committee in its meeting held on 26th October, 2023 for placing it before the Bridges Standards & Specifications Committee (BSS). The list of personnel of B-1 Committee is as under:

| | | |
|---|---|---|
| Sinha, N.K | ..... | Convenor |
| Kumar, *Late* Ashok | ..... | Co-Convenor |
| Goel, Dr. Rajeev | ..... | Member-Secretary |

***Members***

Ahluwalia, Ajay
Ahuja, Rajiv
Arora, H.C.
Bagish, *Late* B.P.
Bambole, Dr. Abhay
Basa, Ashok
Joshi, N.C.
Kanhere, D.K.
Kulkarni, Shriram B.
Kumar, V. Senthil
Matsagar, Prof. Vasant
Mayur, P.V.
Parmar, Anil
Prakash, Dr. S. Suriya
Rao, Prof. N.V. Ramana
Rastogi, D.K.
Sharan, G.
Sharma, R.S.
Topale, Surendra
Verma, G.L.
Zoramliana, H.

***Corresponding Members***

Bijewar, Praveen
Guha, Tanmoy
Rao, Dr. M.V.B.
Shankaralingam, C.
Thite, Tanaji

***Ex-Officio Members***

President,
Indian Roads Congress

(Vasava, S.B.)
Housing Commissioner,
Gujarat Housing Board

Director General
(Road Development) &
Special Secretary to Govt. of India

(Prasad, P.V.S.S.S. Ravi)
Ministry of Road
Transport & Highways

Secretary General,
Indian Roads Congress

(Nirmal, S.K.)

The draft document was recommended by the Technical Standing Panel, appointed by the Convenor in its meeting held on 13th November, 2023. The finalized draft was placed before the Bridges Specifications & Standards Committee (BSS) in its meeting held on 18th November, 2023 and was approved for placing before the EC & Council for their consideration. After due deliberation on the draft document the Executive Committee in its meeting held on 1st December, 2023 approved the same for placing before the Council. The draft document was approved by the IRC Council in its 226th Meeting held on 2nd December, 2023 at Gandhinagar (Gujarat) for printing.

## 100 SCOPE

This Code deals with general features of design of road bridges including immediate approaches and the recommendations of this code apply to all types of bridges. Emphasis has been laid on the safety aspects in planning, design, construction, maintenance & operation.

## 101 DEFINITIONS

### 101.1 Abutment

Abutment is a sub-structure component which supports the end of a superstructure and retains part or whole of the approach fills.

### 101.2 Afflux

Afflux is the rise in the flood level of the channel, immediately on the upstream of a bridge, as a result of obstruction to natural flow caused by the construction of a bridge and its approaches.

### 101.3 Approach

It is a part of road which connects the road to the abutment of the bridge.

### 101.4 Approach Slab

An approach slab is a transition slab of reinforced concrete laid on immediate approaches to a bridge with one end resting on dirt wall / abutment.

### 101.5 Bearing

Bearing is a part of bridge structure which bears directly all the loads from the superstructure of the bridge and transmits the same to the supporting substructure while accommodating the designated movements.

### 101.6 Bridge

A bridge is a structure having a total length of 6 m or more, measured along its axis between inner faces of dirt walls, for carrying traffic or other moving loads across a channel, depression, road or railway track or any other obstruction.

### 101.7 Camber

Camber is transverse inclination given to the cross-section of the carriageway so as to ensure its proper drainage.

### 101.8 Causeway

Causeway is a paved submersible structure across a channel on a road, with or without openings (vents) which allows flood/water to pass through and/or over it.

### 101.9 Channel

Channel is a natural or artificial water course.

### 101.10 Clearance

Clearance is the shortest distance between the boundaries at specified positions of a bridge / underpass / overpass.

### 101.11 Cofferdam

Cofferdam is a temporary structure built for the purpose of excluding water or soil from working area to permit construction without the need for excessive pumping.

### 101.12 Crash Barrier

A safety barrier provided at the side of carriageway designed to reduce the risk of serious accidents by guiding the errant vehicles back on the road.

### 101.13 Culvert

Culvert is a structure on a road having a total length of less than 6 m, measured at right angle between inner faces of walls / dirt walls. Cross drainage structures with pipes will be termed as culvert, irrespective of length.

### 101.14 Dirt Wall

Dirt wall is a vertical wall projecting from abutment cap to prevent spill of earth / pavement materials and also to support approach slab.

### 101.15 Effective Linear Waterway

Effective linear waterway is the total width of waterway of bridge at Highest Flood Level (HFL) minus the effective width of obstructions.

### 101.16 Flyover/Overpass

A flyover or overpass is a bridge structure carrying a road for allowing uninterrupted passage of traffic across congested area, another road or intersection or interchange or any other obstacle.

### 101.17 Foot Over Bridge (FOB)

A foot over bridge is a bridge over a road or any other obstructions, for exclusive use of pedestrians.

### 101.18 Foundation

Foundation is that part of a bridge structure which is in direct contact with the founding strata. It supports substructure and transmits loads to the founding strata.

### 101.19 Free Board

Free board at any point is the difference between the highest flood level after allowing for afflux, if any, and the formation level of road embankment on the approaches or top level of guide bunds at that point.

### 101.20 Full Supply Level (FSL)

Full supply level is the water level corresponding to the full water supply of canal.

### 101.21 Grade Separator

Grade separator is the structure provided on any highway or at-grade intersection or another grade separator or interchange, for facilitating the uninterrupted movement of trafficat different levels.

### 101.22 High Level Bridge

A high-level bridge is a bridge which carries the roadway above the Highest Flood Level (HFL) of a river / channel (including afflux) or the high tide level, with appropriate vertical clearance.

### 101.23 Highest Flood Level (HFL)

Highest flood level is the level of highest flood recorded / observed or calculated from the design discharge, whichever is higher.

### 101.24 Interchange

An interchange is a combination of structures, ramps and grade separations at the junction of two or more highways to provide for the uninterrupted movement of traffic between two or more roads, so as to increase traffic capacity and improve safety.

### 101.25 Invert

An invert is the lowest point of the internal cross section of a culvert or a cross drainage structure.

### 101.26 Kerb

A raised concrete section, forming an edge between the carriageway and railing / footpath / median.

### 101.27 Kerb Shyness

Kerb shyness is the distance by which the driver would generally keep his vehicle away from the kerb in order to avoid brushing with the kerb.

### 101.28 Lateral Clearance of Underpass

Lateral clearance of an underpass is the minimum distance between the extreme edge of the carriageway and the face of nearest obstruction such as abutment, pier, column etc.

### 101.29 Length of a Bridge

Length of a bridge structure shall be taken as the overall length measured along the centre line of the bridge between inner faces of dirt walls (or between end deck joints or outer edge of deck, where there is no dirt wall).

### 101.30 Low Water Level (LWL)

Low water level is the level generally prevailing in the stream / river during dry weather.

### 101.31 Ordinary Flood Level (OFL)

Ordinary flood level is the level to which the stream / river generally rises during monsoon period every year.

### 101.32 Overpass

See 101.16 Flyover / Overpass.

### 101.33 Parapet

Barrier installed on the edge of a bridge / culvert from safety considerations and intended to restrain users from falling off the bridge.

### 101.34 Pier

Pier is an intermediate support of the bridge super-structure.

### 101.35 Ramp

Ramp is road in slope, connecting roads at different levels.

### 101.36 Retaining Wall

Retaining wall is a wall designed to retain earth fill.

### 101.37 Return Wall

Return wall is a wall adjacent to abutment and parallel to center line of road to retain approach embankment.

### 101.38 Right of Way (ROW)

Right of way is the land made available and / or acquired for development of road.

### 101.39 Road Over Bridge (ROB)

Road over bridge is a bridge built over the Railway tracks.

### 101.40 Road Under Bridge (RUB)

Road under bridge is a structure built beneath the Railway tracks.

### 101.41 Safety Kerb

A kerb having width of at least 750 mm for occasional use by pedestrians, where footpath is not provided.

### 101.42 Skew Angle

Skew angle is the angle between the axis of support and a line normal to the longitudinal axis of a bridge.

### 101.43 Span

Span is the horizontal distance between the centre lines of adjacent supports of a bridge superstructure, or maximum distance between the inner walls of a culvert, measured alongits axis.

### 101.44 Submersible Bridge

Submersible bridge is a bridge designed to be overtopped during floods.

### 101.45 Substructure

Substructure is the portion of a bridge structure between the foundation and the superstructure.

### 101.46 Subway

A subway is usually meant for pedestrian use and comprises of structure below a road with stairs / ramps / escalator.

### 101.47 Super Elevation

Super elevation is transverse inclination given to the cross section of a carriageway on a horizontal curve in order to reduce the effects of centrifugal force on a moving vehicle.

### 101.48 Superstructure

The portion of a bridge structure above bearings, which directly supports pedestrian / vehicular /other transient loads and transfers the same to the substructure.

### 101.49 Toe Wall

Toe wall is a wall built at the end of the slope of earthen embankment to prevent slipping of earth and / or pitching.

### 101.50 Tunnel

Tunnel is an underground closed structure carrying a roadway, through soil or rock.

### 101.51 Underpass

Underpass is a structure allowing uninterrupted movement of traffic beneath a roadway, railway, or intersection. An underpass is classified as Cattle Underpass (CUP), Pedestrian Underpass (PUP) and Vehicular Underpass (VUP) based on its intended use.

### 101.52 Vertical Clearance

For a channel, vertical clearance is the height from the design flood level with afflux or high tide level, to the lowest point of the super structure, at the position along the bridge where clearance is being denoted. For flyover, underpass, overpass, ROB and RUB, the vertical clearance is the height above the highest point of road surface or rail top level to the corresponding lowest point of the superstructure.

### 101.53 Viaduct

A viaduct is a bridge structure constructed on dry ground / terrain.

### 101.54 Wearing Course

It is the top layer of a road surface over deck that protects the main superstructure and takes the wear caused by traffic.

### 101.55 Width of Carriageway

Width of carriageway is the minimum clear width measured at right angles to the longitudinal center line of the bridge between inside faces of crash barrier / kerbs / median.

### 101.56 Wing Wall

Wing wall is a splayed return wall, usually at angle of 30° to 45° to the road embankment.

### 101.57 Railings

Bridge railings are barriers provided to prevent users from falling off the bridge.

### 101.58 Footpath

A footpath is a type of thoroughfare on bridge structure that is intended for use only by pedestrians.

### 101.59 Noise Barrier

The structure generally provided on the outer edges of superstructure to mitigate the impact of excessive noise pollution generated by traffic at sensitive locations like hospitals, educational institutions, residential colonies, etc.

# 102 CLASSIFICATION

Bridges are classified on the basis of their principal function or purpose, material used in construction, length, structural form, system of support, construction technology and deck level with respect to highest flood level. The broad details of bridge classification are as follows:

## 102.1 Function or Purpose

Based on functions, bridges are classified as under:

a) River bridge / Bridge over stream – navigational / non-navigational
b) Viaduct
c) Flyover
d) Grade separator
e) Road Over Bridge (ROB)
f) Road Under Bridge (RUB)
g) Foot Over Bridge (FOB)
h) Underpasses
i) Subways
j) Overpass
k) Aqueduct carrying a river or a canal
l) Pipeline or Conveyor bridge
m) Road cum Rail bridge
n) Movable / Swing Bridges

## 102.2 Length

**102.2.1** Based on length, structures are classified as below:

a) Culvert: as defined in clause 101.13
b) Bridge: as defined in clause 101.6

**102.2.2** The bridges are further classified as minor and major bridges as below:

a) Minor bridge is a bridge having a total length of up to 60 m.
b) Major bridge is a bridge having a total length of more than 60 m.

**102.2.3** Bridges having span length(s) of 150 m or more are classified as 'longspan bridges.'

## 102.3 Superstructure

### *102.3.1 Form of Superstructure*

Based on form and type of superstructures, bridges are classified as under:

a) Solid slab
b) Voided slab
c) Beam and slab
d) Arch
e) Suspension
f) Cable stayed

g) Extra-dosed
h) Box girder
i) Single / Multi-cell Box type structure
j) Truss

### *102.3.2 System of Support for Superstructure*

Bridges are classified on the basis of systems of support as under:

a) Simply supported
b) Continuous
c) Integral and Semi-integral bridges
d) Balanced cantilever
e) Framed bridges
f) Cable supported

## 102.4 Material

Based on material of structure, bridges are classified as under:

a) Brick or stone or concrete block masonry
b) Concrete – plain, reinforced, and prestressed
c) Fiber reinforced concrete and ultra-high performance fiber reinforced concrete
d) Structural steel
e) Steel-concrete composite
f) Timber
g) Fiber reinforced polymers or composite materials

## 102.5 Construction Technology

Based on construction technology adopted, bridges are classified as under:

a) In-situ
b) Precast or prefabricated
c) Cantilever
d) Incremental launching
e) Span by span
f) Segmental.

## 102.6 Level

River Bridges / Bridges over streams are classified based on roadway level with respect to High Flood Level (HFL), as under:

a) High level bridge
b) Submersible bridge

## 102.7 Importance

Based on the importance of a bridge in the highway system, bridges are classified as under:

a) Normal
b) Important
c) Critical

### 102.8 Alignment

a) Straight
b) Skew bridge
c) Curved bridge

### 102.9 Location of bridge deck relative to the superstructure

a) Deck bridge
b) Through bridge
c) Semi-through bridge
d) Suspended bridge

### 102.10 Fixed or Movable

a) High - level fixed
b) Movable bascule
c) Movable / swing bridge.
d) Transporter bridge
e) Floating Bridge

### 102.11 Type of service

a) Permanent
b) Temporary

## 103 GENERAL PROVISIONS

### General

The design shall be principally based on the limit state design philosophy. Structural components and the connections shall be designed to conform to the requirements of ultimate limit state, serviceability limit state and fatigue limit state of the relevant codes of IRC.

### 103.1 Performance Requirements

Bridge structure and its components shall be planned, designed, constructed and maintained in such a way that they perform adequately and safely during construction and service life, with following performance requirements:

a) Structural Safety and Serviceability, i.e., ability of a structure or structural members to perform, with appropriate levels of reliability, adequately for normal use under all combinations of actions expected during construction and service life.

b) Durability, i.e., ability of the structure to perform during design service life, for its intended purpose with anticipated maintenance but without major repair being necessary.

c) Economy, i.e., bridges should have least life cycle cost.

d) Sustainability, i.e. ability of a material, structure or structural member to contribute positively to the fulfillment of the present needs and the needs of future generations.

Above requirements may be met by

i) The choice of suitable materials.

ii) Appropriate design and detailing.

iii) Specifying control procedures for design, production, execution, and use relevant to the particular project.

iv) Appropriate choice of span arrangement and construction methodology.

## 103.2 Structural Safety & Serviceability

Structural safety is ability of a structure and its structural members to guarantee the overall stability, adequate deformability and ultimate bearing resistance, corresponding to the assumed actions (both extreme and / or frequently repeated actions and accidental and / or exceptional events) with appropriate levels of reliability for the specified reference periods. The structural safety shall be analyzed for all possible damage states and exposure events relevant for the design situation under consideration.

In the context of performance-based Limit State Design, performance criteria for serviceability and structural safety are specified by:

a) Serviceability limit state criteria

b) Ultimate limit state criteria

Limit state shall be related to design situations. They may relate to persistent situations during the service life of the works, transient situations during the construction stage as well as repair stage, extreme actions and environmental influences, including earthquakes. Design principles with respect to the performance-based Limit State Design for structural safety and serviceability as given in relevant design codes of IRC may be adopted.

Serviceability limit state corresponds to the state beyond which specified performance requirements for a structure or a structural component are no longer met.

Ultimate limit state is the limit state associated with the structural collapse leading to loss of life, damage to structure and environment and disruption of operation. Ultimate limit state may arise due to structural components reaching their ultimate strength, fatigue or instability.

## 103.3 Economy

Economy in bridge design would generally depend upon structural type, span arrangement, materials and method of construction, which shall be selected on the basis of life cycle cost. Costs of structural alternatives should be worked out based on long term considerations including

inspection, maintenance and repair / replacement. Therefore, cost of future expenditure on repair and maintenance during the whole service life of bridges should be accounted for. Construction cost shall take into account regional factor such as availability of material and labour, fabrication, location, shipping, erection constraints and diversion road. Cost on account of mitigation of social and environmental impact shall also be taken into account in working of cost comparison.

### 103.4 Sustainability and Loading Considerations

The structures shall contribute towards sustainable development by effective mitigation of social and environmental impacts.

The loads, special local conditions and traffic intensity for which a bridge is to be designed, shall be prescribed by the authorities as per relevant clauses of IRC:6.

Utilities or services, if any, to be carried over the bridge and if so, nature thereof (e,g. Telephone Cables, OFC etc.) and relevant information regarding size, arrangement etc. shall be taken as per the requirements or as directed by the authorities.

## 104 PLANNING CONSIDERATIONS

Planning of a bridge is essential to create a facility which will comply with various functional, technical, environmental, social, administrative, landscaping, and safety requirements including financial justifications besides serving its intended purpose. All requisite information and data shall be collected for proper planning of a bridge project.

### 104.1 Planning Strategies

#### 104.1.1 *Integration with Road Network*

The first step in the planning of a bridge project is to ascertain its location in the link of the road network and function thereof. The bridge shall fit into the road link in a seamless manner and contribute to its primary function. Most road links have both mobility and accessibility functions in varying degrees, which shall be taken into account while planning.

#### 104.1.2 *Interaction with other Authorities and Public*

It is necessary to interact with authorities and local public who are directly or indirectly connected with the project or whose works or authority will be directly or indirectly affected.

#### 104.1.3 *Siting of a Bridge*

104.1.3.1 River bridge

a) A bridge should ideally be sited across the narrowest width of the river or channel where the course of the channel is straight in considerable length on both up-stream and down-stream sides of the site and the banks are stable having no history of being out-flanked. A bridge should not be sited across meandering stretches of rivers unless it is established that the banks at the bridge site are the nodal points of the river (i.e., the river has a history of touching these points year after year regardless of change in its course elsewhere). Where one of the banks is not well defined and gets over-topped, the option of training the river by construction of a guide bund can also be considered. In case the active channel of the river, especially the alluvial rivers, changes its course within the river basin, the option of training the river by construction of guide bunds on

both banks can be considered after ensuring that the adjoining areas in the upstream do not get flooded or the guide bunds themselves are not under attack. The preliminary site selection can be based on information contained in the topographical sheets of the Survey of India, supplemented by actual survey or study of satellite images of the location, which can be obtained from the National Remote Sensing Agency. A model study may be required for bridging rivers having undefined cross section and huge flood plains.

b) The cardinal principles to be kept in view at the time of selection of a particular bridge site including river training works are to provide a suitable crossing consistent with safety and economy and acceptable detour from the existing road alignment. The following shall be the guiding considerations in this regard:

   i) **Bridges up to a length of 60 meters** - The location shall be governed by suitability of alignment of road, unless there are special problems at the crossing with regard to design and maintenance of the bridge.

   ii) **For bridges having a length between 60 m and 300 m** - Suitability of site of the bridge as well as that of the alignment of approaches shall be considered together.

   iii) **For bridges having a length more than 300 m** - The requirement of a good site for the bridge shall have the precedence and the alignment of approaches will have to conform to the selected bridge site.

c) A brief description of the reasons for selection of a particular site for the crossing should be prepared for record, which shall include typical cross- sections of the channel at all alternative sites investigated and rejected.

104.1.3.2 Grade separators and underpass

The layout of a grade separator or an underpass is determined by the alignment and geometry of intersecting roads, traffic, road classification, degree of required segregation, location either in inhabited or uninhabited area, topography of the region, land availability and intended purpose.

104.1.3.3 Bridges in hilly & coastal regions

a) For bridges in high altitude, where the road is likely to pass through snow bound areas and avalanche prone slopes, snow removal and avalanche control should be one of the factors to be considered in the planning stage of the road and bridges. Specialist literature and publications shall be referred to for dealing with such cases.

b) The coastal bridges are susceptible to highly corrosive environment, storm surge or tsunami and strong cyclonic winds. Specialist literature and publications shall be referred in absence of any relevant IRC standards.

104.1.3.4 Approaches

A length of at least 50 m of approaches on either side of the bridge / grade separator or the defined length up to the end of approach gradient, whichever is larger, shall form part of bridge / grade separator planning. The approaches of a flyover may comprise series of viaduct spans for openness in inhabited locality or wall type structures in remote areas.

### 104.1.4 *Design Life*

Design Life is the period during which the bridge or its components are able to perform its intended and design functions with requisite safety to its users, subject to regular inspection and maintenance and repairs.

A bridge can be divided into structural (non-replaceable) components (e.g., deck, superstructure, pylons or towers, abutments, piers, pier caps, etc.) and ancillary (replaceable) components (e.g., bearings, expansion joints, wearing surface, drainage system, etc.) having different design life. To achieve a limited impact on traffic, design life requirements for replaceable components may be set such that the design life of non-replaceable components is reached after one or more replacements of replaceable components. Besides, Maintenance Manual shall be prepared to meet the target design life as a part of the structural design process. Design life of structural and ancillary components is given below:

| S. No. | Component | Design Life |
|---|---|---|
| 1. | All structural components | 100 years<br><br>(Depending upon importance, strategic needs and criticality of the bridge, a higher design life may be prescribed by the authorities). |
| 2. | Ancillary items like bearings, expansion joints, wearing course etc. | As per provisions of respective Codes of Practice (Provision for replacement of these items shall be ensured in design and drawings) |

### 104.1.5 *Safety*

The bridge and its approaches shall be planned to ensure the safety of the user and the structure in accordance with Clause 105.2.

### 104.1.6 *Initial Environmental Examination*

Initial environmental examination should be carried out to evaluate likely adverse impact of the proposed bridge on environment. The most likely impacts are as under:

a) Increase in submergence of surrounding area
b) Likelihood of river bank erosion
c) Possibility of siltation
d) Relocation and rehabilitation of people / communities
e) Effects on historic monuments and heritage structures
f) Impact on conservation of wildlife, flora and fauna
g) Impact on surroundings

### 104.1.7 *Aesthetics*

All bridges and grade separators should be aesthetically pleasing and should blend with the environment as it has a large impact on the surroundings. Considerations shall be given to various aspects mentioned in Clause 112.

### 104.1.8 *Economic Evaluation*

The economic evaluation of different alternatives of a bridge project shall be carried out to determine its relative viability. In some cases, social, strategic and connectivity requirements may prevail over the economic considerations.

## 104.2 Collection of Data

All detailed information for a complete and proper appreciation of the bridge project shall be included in the project documents. Generally, the following information shall be furnished.

a) General Data including Maps, Plans and Topographical Features
b) Hydraulic Data for Selected Bridge Site
c) Geological and Seismological Data for Selected Bridge Site
d) Geophysical Investigation
e) Sub-surface Data
f) Environmental Data
g) Social Impacts
h) Loading and other Data
i) Traffic Data
j) Construction Materials
k) Special Design Requirements
l) Existing Services
m) Labour Accommodation
n) Other Authorities
o) Data Regarding Existing Bridges
p) Accessibility to the site and availability of space for casting yard

## 104.3 Width of Carriageway, Footpath and Median

### 104.3.1 *Width of Carriageway*

*a) Bridges:*

For all highway bridges (other than on expressways), the width of carriageway shall be at least 4.25 m for a single lane bridge, for a two-lane bridge as 2 x 3.5 m + 2 x kerb shyness and shall be increased by 3.5 m for every additional lane of traffic for multiple lane bridge. For expressways, minimum carriageway width shall be 2 x 3.75 m + 2 x kerb shyness for a two-lane bridge and shall be increased by 3.75 m for every additional lane of traffic for multiple lane bridge. The clear width of the bridge between the inside faces of crash barrier / kerbs shall be sum of the carriageway width, paved shoulder width (if provided) and kerb shyness. If a median / central verge is constructed in a wide bridge thus providing two separate carriageways, the carriageway on each side of the median shall provide at least two lanes of traffic and width thereof shall individually comply with minimum requirements stipulated above. For a bridge on horizontal curve, the roadway width shall be increased suitably to conform to the requirements stipulated in relevant IRC Standards.

*b) Culverts:*

In plain and rolling terrain, the overall width on culverts (measured from outside to outside of the parapet walls) should be equal to the normal roadway width on approaches. In mountainous and steep terrain, the clear roadway width available on the culverts (measured from inside to inside of parapet walls or kerbs) should be calculated based on the widths of the corresponding roadway elements.

**104.3.2** Overall width of bridge deck shall be sum of widths of carriageway, kerb shyness, crash barrier, paved shoulder, footpath or cycle / motorcycle or two – wheeler track, kerbs and railing / crash barrier. In case of combined superstructure for both directions of traffic, width of median may also be added.

**104.3.3** ***Deck width of Bridges and Structures on National Highways***

a) Footpath shall be provided on all major bridges and RoBs. Footpath shall be provided on minor bridges in built up areas only.

b) Outer to outer deck width of bridges, where no footpaths are provided, shall be matched with outer to outer of approach road including earthen shoulders.

c) In case footpath is provided on the bridge, carriageway and paved shoulders shall be carried on the bridge deck placing footpath (1.5 m clear) on the outer edge of paved shoulder with crash barrier (0.45 m) on inner side and railing (0.375 m) on outer side.

d) Lines and grades of paved shoulder, median edges, carriageway on bridges and approaches shall be matched for safety and efficient traffic movement.

**104.3.4** Provision for increased width of carriageway for future widening of the bridges and culverts may be made as per the project requirement and as decided by the authorities.

**104.3.5** Vented causeway / submersible bridges, if provided, shall cater for at least two lanes of traffic.

**104.3.6** Width of bridge carrying combined highway / Mass Rapid Transport System (MRTS) / Railway corridor:

For bridges carrying combined road and rail or any other special type of traffic, the widths indicated in the above clauses shall be suitably increased.

**104.3.7** ***Width of Median***

The median width of the approach road shall generally be carried over the bridge when both side carriageways are supported on a single deck. In case of space constraints,the median width may be reduced on the bridge, subject to a minimum width of 1.20 m, in which case, crash barriers and anti-glare measures shall be provided in the median.

**104.3.8** ***Width of Footpath***

When a footpath is provided, its clear width shall not be less than 1.5 m. For urban and populated areas having large concentration of pedestrian traffic, the width of the footpath shall be suitably increased.

## 104.4 Clearances

### 104.4.1 *Clearance - Navigational*

Navigational clearances, both vertical and horizontal, shall be provided based on classification of waterway as per the requirements of Inland Waterway Authority of India (IWAI) or the concerned Port authorities.

### 104.4.2 *Clearance – Over Roads*

104.4.2.1 Vertical Clearance

For underpass and overpass, vertical clearance shall be provided after considering atleast 250 mm (for future strengthening and accidental margin requirements) above the finished road level. Vertical clearances at under pass / overpass shall not be less than the values given below.

**Table 1 Minimum Vertical Clearance of Underpass / Overpass**

| Sl. No. | Type of Underpass / Overpass | Minimum Vertical Clearance (m) |
|---|---|---|
| 1. | Vehicular Underpass | 5.5 |
| 2. | Light Vehicular Underpass | 4.0 |
| 3. | Smaller Vehicular Underpass | 4.0 |
| 4. | Pedestrian Underpass | 3.0 |
| 5. | Cattle Underpass | 3.0 |
| 6. | Vehicular Overpass | 5.5 |

***Note**: 1. In case the project road passes through forest / wildlife zones, appropriate vertical clearances must be provided for animal passages based on the type of crossing animals (such as Elephant, Camel, Tiger, etc.) as per local requirement and directions / regulations issued by Ministry of Environment, Forest and Climate Change.*

*2. Concerned authority may reduce the vertical clearance given in the Table-1, due to constraints.*

104.4.2.2 Lateral / Horizontal Clearances

For underpass / overpass, full roadway width at the approaches should be carried through the underpass / overpass. While fixing the horizontal clearance, consideration shall be given to safe passage of vehicles on or under a bridge. Guard rails / crash barrier shall be provided for protection of vehicles from colliding with the abutments, piers and the deck of the structures. The minimum lateral / horizontal spans to ensurerequired clearances shall be provided as given in the Table 2.

**Table 2 Minimum Lateral / Horizontal Span of Underpass / Overpass**

| Sl.No | Type of Underpass / Overpass | Minimum Horizontal Clear Span (m) | Remarks |
|---|---|---|---|
| 1. | Vehicular Underpass | 12.0 | |
| 2. | Light Vehicular Underpass | 10.5 | |
| 3. | Smaller VehicularUnderpass | 7.0 | |
| 4. | Pedestrian Underpass | 7.0 | |
| 5. | Cattle Underpass | 7.0 | |
| 6. | Vehicular Overpass | * | *Full roadway width including service road and future widening |

***Note***- *Concerned authority may reduce the clearance given in the Table-2 due to constraints. For a bridge constructed on a horizontal curve with super elevated road surface, the horizontal clearance shall be increased on the side of the inner kerb by an amount equal to 5 m multiplied by the super elevation. Extra horizontal clearance required for the super elevation will be over and above the increase in width required on a curve.*

### 104.4.3 *Clearance - Over Railway Lines*

For ROBs across railway lines, horizontal and vertical clearances shall be governed by the requirements of the Railway authority.

### 104.5 Span Configuration

**104.5.1** Choice of a particular span arrangement and the type of structure depends upon several factors such as site characteristics, type of sub-soil strata, height and length of the bridge, riding quality, design and, constructability considerations, availability of construction material and technology etc. In case of urban flyovers, considerations of aesthetics and other functional requirements like openness in inhabited portions, may have overriding effect for viaduct spans vis-a-vis solid-fill portion for approaches.

**104.5.2** For all bridges, efforts shall be made for keeping minimum number of expansion joints, for ensuring better riding quality.

**104.5.3** Span shall be selected in such a way which can preferably ensure the use of precast structural elements and high strength materials for enhanced quality and increased durability.

## 105 GEOMETRIC DESIGN CONSIDERATIONS

### 105.1 General

Geometric design for the bridge including immediate approach roads should essentially include integration of vertical and horizontal alignment of the bridge with the highway geometry, as per IRC SP 54 and should broadly cover the following:

a) **Preparation of Plan** - Showing the horizontal alignment, horizontal curves, overall width, width of carriageway, footpath, median, crash barrier, railing, shoulders, side drains, right of way, etc.

b) **Preparation of Vertical Profile** - Showing the vertical alignment, grade line, vertical curves, high flood level, ground / bed profile etc.

c) **Preparation of Cross-Sections** - Showing the carriageway, cross camber / super elevation, side slopes, median, footpath, hydraulic details, structural arrangement, type of superstructure, substructure and foundation, abutment details, protection works, details of return walls, retaining walls etc.

## 105.2 Safety Considerations

### 105.2.1 *Protection to User*

Railings / Crash Barriers shall be provided along the edges of structures conforming to the requirements stated elsewhere in the code. Footpaths and cycle / two-wheeler track adjacent to the carriageway shall have crash barriers between main carriageway and footpath / two-wheeler track, to safely redirect the errant vehicular traffic.

### 105.2.2 *Protection to Structure Against Vehicle Collision*

Considerations for adequate horizontal and vertical clearances shall be given for safe passage of traffic under a bridge. The hazard of substructure and / or exposed portion of foundation being hit by errant vehicles within the clear zone should be minimized by locating structural components at a safe distance from the line of users and/or by providing suitable protection to the structural components.

### 105.2.3 *Protection to Structure Against Barge Impact*

For bridges on streams / sea / creek where barges are plying, the bridge structure shall be protected against vessel collision forces by fenders, protection islands or any other means. Alternatively, the structural system shall be designed to withstand the effects of collision force as specified in relevant IRC Code.

## 105.3 Horizontal and Vertical Alignments

Horizontal and vertical alignments of road bridges shall conform to relevant IRC Code. While finalizing the horizontal and vertical alignment for the bridge portion, following aspects shall be considered:

**105.3.1** To the extent practicable, the alignment of roadways shall be selected to make bridge crossing as nearly square as possible.

**105.3.2** Wherever the bridge is in curvature, effort shall be made to provide constant curvature within the bridge portion of the highway. Sudden change of radii and curvature over the bridge shall be avoided to the extent possible.

**105.3.3** Skew Angle in any Bridge should preferably not exceed 30 degrees.

**105.3.4** In situations where a replacement / new bridge is to be constructed adjacent to an existing structure, the width of the gap between the two bridges shall be decided on the basis of clearance between the foundations. Not less than 2.5 m clear gap should be provided at any place between the superstructures of the two bridges to allow for working space.

**105.3.5** Locating bridges on vertical sag curves shall be avoided as far as possible, as vehicle dynamic effects are increased and appearance is adversely affected.

**105.3.6** A minimum longitudinal gradient of 0.3% is desirable for providing effective drainage of deck.

**105.3.7** The combined effect of horizontal and vertical alignments and changes in super elevation shall be considered with regard to the appearance of the bridge structure, especially in urban situations.

**105.3.8** A single vertical curve shall be provided for bridges on a summit curve having total length up to 30 m.

## 105.4 Design Speed

Design speed over the bridge shall be consistent with the design speed on the approach roads. A single design speed should preferably be adopted for the entire bridge structure. In case, however, differential design speed is unavoidable due to presence of sharp curvatures in specific zones within the bridge, transitions between sections with different Design Speeds shall be designed as per relevant IRC codes.

## 105.5 Longitudinal Gradient and Cross Slope

**105.5.1** The maximum longitudinal gradient on bridge shall be consistent with the gradient of the approach roads as per relevant IRC codes.

**105.5.2** The cross slope on bridge deck shall be consistent with the cross slope of the adjoining roadway.

**105.5.3** During exiting a bridge, consideration shall be given to stopping sight distance, especially where bridge approaches are constructed close to intersections.

## 105.6 Super-Elevation

**105.6.1** The super elevation and additional widening on the deck of a bridge on a horizontal curve shall be provided in accordance with relevant IRC Code.

**105.6.2** Transition from normal cross slope to full super elevation shall be avoided over a bridge as far as possible.

## 105.7 Approaches to Bridge

**105.7.1** The approaches on either side of the bridge for a length of at least 15 m shall continue to have the same horizontal profile as that provided for the bridge. This length may be suitably increased where necessary to provide for the minimum sight distance for the design speed. However, in difficult geometric situations, the minimum length of approaches with same horizontal profile may not be insisted upon, provided user's safety concerns are not compromised.

**105.7.2** Where horizontal curves have to be provided on the approaches, beyond the straight portion on either side, the minimum radius of curvature, the super elevation and transition length for various speed and curve radii shall be provided in accordance with stipulations contained in the relevant IRC Codes.

**105.7.3** If there is a change of gradient in the approaches, suitable vertical curves shall be introduced conforming to stipulations contained in relevant IRC Codes.

## 106 HYDROLOGY AND HYDRAULIC DESIGN

**106.1** Data collection for hydraulic design shall be made in accordance with Clause 104.2 of the code.

### 106.2 Determination of Design Highest Flood Level

**106.2.1** The design flood level shall be decided on the basis of data collected during reconnaissance survey, aerial survey, satellite maps, detailed survey and hydrological and hydraulic studies and analyses made.

**106.2.2** Design Highest Flood Level shall be the Highest of the following:

a) The highest of flood levels as obtained from local enquiries from aged persons. Such local enquiries should be made at 3 different locations at site.

b) Level of the highest watermarks, left on different old structures or the erosion marks on the banks.

c) Highest flood level that will be able to pass the design discharge as determined from other sources as per clause 106.3.

d) The highest of the levels after considering the effects of confluence, backwater and HFL because of merger of or into any other river in the influence zone upstream or downstream of site.

e) The highest level as corroborated from the records of HFL available for existing bridges, other structures like dams and spillways and gauge stations etc. on the river in upstream or downstream direction.

f) Effect of any new structure planned for future in the influence zone of the stream.

### 106.3 Determination of Design Discharge

**106.3.1** The design discharge for which the waterway of the bridge is to be provided, shall be based on maximum flood discharge of return period of 100 years. In case where the requisite information is not available, the design discharge shall be the maximum estimated discharge determined by consideration of the following or any other rational method.

106.3.1.1 From the records of discharge observed in the stream at the site of the bridge, or at any other site in its vicinity i.e., the discharge taken for design at any other bridge site and any other irrigation structures like dam or spillway or Gauge station on this river in the upstream direction.

106.3.1.2 From the rainfall and other characteristics of the catchment:

i) By the use of an empirical formula, applicable to that region, provided that empirical formula can predict the maximum discharge for given return period.

ii) By a recognized method, provided it is possible to evaluate, for the region concerned, the various factors employed in that method.

106.3.1.3 From stage discharge curves, if available

106.3.1.4 By the area velocity method with the help of hydraulic characteristics of the channel. In case of the river not confined within banks and flowing in larger widths, the flow width should be divided into suitable zones i.e., main flow channel, side flow channel, slow channel and stagnant or no flow channel depending upon the characteristics and various parameters which should also be considered accordingly for calculation of discharge from that zone.

106.3.1.5 By unit hydrograph method (see **Appendix-1**)

Flood estimation reports in respect of total 21 climatic sub-zones **(Appendix-1(a))** in the country have been prepared based on the hydro-meteorological data collected for selected catchments of areas varying from 25 to 1500 sq.km. and are available with the Director, Hydrology (small catchments), Central Water Commission. The methodology recommended in the relevant sub-zone report pertaining to a particular region may be followed for assessment of maximum discharge for the design of bridges.

**106.3.2** Where possible, more than one method shall be adopted, results compared, and the maximum discharge fixed by judgment by the engineer responsible for the design. The bridge shall be designed for this maximum discharge. However, for catchment areas covered by sub-zones mentioned in **Appendix 1(a)**, the maximum discharge shall be assessed on the basis of the flood estimation report for the said sub-zone.

**106.3.3** Various limitations of the methods for computing the Maximum Design Discharge correctly under different flow, bed and site conditions and for a given return period, should be kept in mind and accounted for adequately while deciding the same.

**106.3.4** For minor bridges, where catchment area cannot be defined, reliance may bekept on Area Velocity Method.

**106.3.5** The maximum estimated discharge from the catchment area as calculated above or normal peak flood discharge from the dam / spillway if existing or being proposed in the upstream of the bridge (to be ascertained from the Irrigation Authorities), whichever is more, shall be considered for design of the bridge.

Freak flood discharges or exceptional discharge of high intensity due to the failure of a dam or tank constructed upstream of the bridge need not be catered for.

**106.3.6** In cases where the design discharge cannot be properly quantified and in spill zones of rivers known for flash floods, the abutments may also be designed and detailed as 'piers' for possible future extension.

## 106.4 Discharge for Design of Foundation and Protection Works

To provide for an adequate margin of safety against scour, the foundation and protection works shall be designed for a larger discharge than the design discharge as per Clause 106.3. Such increase in design discharge is given below:

| Catchment Area in $km^2$ | Increase Over Design Discharge in Percentage |
|---|---|
| 0 -3000 | 30 |
| 3000- 10000 | 30-20 |
| 10000-40000 | 20-10 |
| Above – 40000 | 10 |

***Note:*** *i) For intermediate values of catchment area, linear interpolation may be adopted.*
*ii) The minimum vertical clearance above the HFL as computed as per clause 106.8 need not be increased due to larger discharge calculated above.*

## 106.5 Determination of Waterway

### 106.5.1 Linear Waterway

106.5.1.1 For natural channels in alluvial beds but with well-defined banks and for all natural channels in beds with rigid in-erodible boundaries, the linear waterway shall be distance between banks at HFL, at which the designed maximum discharge determined in accordance with Clause 106.3, can be passed.

106.5.1.2 For natural channels in alluvial beds and having undefined banks, the linear waterway shall be determined from the design discharge using some accepted rational formula at the discretion of the engineer responsible for the design. One such formulafor regime conditions is:

$$W = C\sqrt{(Q)}$$

Where,

W = regime width in meters (equal to effective linear waterway under regime condition)

Q = the maximum design discharge in $m^3$/sec;

C = a constant usually taken as 4.8 for regime channels, but it may vary from 4.5 to 6.3 according to local conditions.

106.5.1.3 The formula which is applicable for alluvial soils in regime conditions, should not be applied for clayey, bouldery or such strata. The waterway in such cases should be decided on the basis of study and analysis of site and flow conditions by adopting some rational approach (like performance of existing bridge nearby, on the same river).

106.5.1.4 In meandering flood plains and in deltaic regions, the waterway proposed may be as in above clauses, but guide bunds, flood embankments or other river training works should be provided to train the river to flow through the bridge. Hydraulic or Mathematical model studies may be required to ascertain the flow conditions, and design parameters for the training works and the required waterway.

106.5.1.5 If the river is of a flashy nature and the bed does not submit readily to the scouring effects of the flood, the linear waterway should be determined by the area velocity method, taking into account the design flood level and its water spread, the characteristics of the bed materials and the water surface slope.

106.5.1.6 In a hilly terrain, the minimum waterway under the bridge should be kept same as the linear waterway at HFL.

106.5.1.7 In sub-hilly terrain / trough terrain, waterway should be decided after carefully studying the past history of river behavior and flow conditions, as river is usually unstable and changing course periodically resulting in a fan shaped delta type formation, requiring more waterway than normally required by formula.

106.5.1.8 In case a new bridge is to be constructed, close to an existing bridge for the purpose of widening or providing extra carriageway, the waterway provided in the new bridge should usually be kept the same as in the old bridge unless there are specific reasons. If the waterway is to be kept different, then bridges should be provided with smooth inlet and outlet transitions.

106.5.1.9 For artificial channels (irrigation, navigation and drainage), the linear waterway should be adequate to pass the full discharge at designed velocity, but concurrence shall invariably be obtained from the authority controlling the channel. If it is proposed to flume the channel at the site of the bridge, this fluming shall be subject to the consent of the same authority and in accordance with the essential requirements.

106.5.1.10 The waterway, as worked out from the formula or decided otherwise, should be compared with linear waterway at HFL corresponding to the design flood discharge and the difference in the two should be analyzed and reconciled before finally deciding the waterway to be provided.

### 106.5.2 Restricted Waterway

106.5.2.1 The linear waterway as calculated above can be restricted by careful consideration of the resulting effects on flow conditions, scour, afflux and other site condition in the individual cases. No restriction in waterway should be considered for well-defined and confined flow.

106.5.2.2 In hilly terrain the linear waterway at HFL should not be restricted because that will cause undesirable hydraulic jumps as the flow in such a terrain is usually super critical.

106.5.2.3 For unstable meandering rivers flowing through a number of sub channels separated by land or shallow section of nearly stagnant water and having width much in excess of the regime width, or channels flowing over large widths with small depths, the restriction of waterway may be considered. In such cases, it may be necessary to constrict the channel by providing training and protection works to prevent the main channel from wandering about freely and for minimizing the resultant oblique attack on bridge foundations and approaches. The extent of constriction and the design of training works in such cases should, preferably, be decided on the basis of model studies, keeping in view the ultimate economy, safety, durability and aiming at optimal recurring maintenance needs of structure as well as river training works.

106.5.2.4 In case of bridge being located at bends, curves or oblique to flow, the waterway gets restricted. The available waterway normal to the flow should be worked out and this should be accounted for in the design.

106.5.2.5 The restriction of waterway will result in afflux on the upstream of bridge. The effect of this afflux on the velocity, scour and submergence of surrounding area should be considered in the design. The consideration of these effect and comparison of consequent costs in the two cases, will decide the limit of restriction in the linear waterway.

106.5.2.6 If the waterway has to be restricted to such an extent that the resultant afflux will cause the channel to discharge at erosive velocities, protection against damage by scour shall be afforded by providing deep foundations, curtain or cutoff walls, rip- rap, bed pavement or other suitable means.

### 106.5.3 Effective Linear Waterway

106.5.3.1 The linear waterway or restricted waterway worked out as above shall be reduced because of the obstruction caused by piers or obliquity of flow in the river at the bridge site.

106.5.3.2 For calculating the effective linear waterway the width of obstruction due to each pier shall be taken as the mean submerged width of the pier and its foundation up to the normal scour level. The obstruction at the ends due to the abutments or pitched slopes duly protected shall be ignored. For other flow conditions, actual obstruction due to pier and foundation normal to the flow should be worked out and considered in design.

106.5.3.3 Effect of presence of Dams, Barrages, Weirs, Sluice Gates etc. on the hydraulic characteristics like causing obliquity and concentration of flow, scour, silting of bed, change in flow levels, bed levels etc. should be studied and analyzed while deciding the waterway. These should invariably be decided after collection of data from the concerned regulatory authorities and after discussions with them.

106.5.3.4 The effect on linear waterway and hydraulic particulars should be taken care of in the design of a bridge, if constructed in the close proximity of an existing bridge.

106.5.3.5 In case of tidal zones, where it is decided to adopt measures likely to affect the volume of the tidal flow and other characteristics of the tide, it shall be ensured that no port or harbor or other installations in the proximity of the bridge are adversely affected.

## 106.6 Determination of Afflux

**106.6.1** If the waterway is restricted as per Clause 106.5.2, it will cause afflux at the bridge and design HFL will accordingly be raised.

**106.6.2** The afflux shall be calculated by using any suitable method based on conservation of energy or momentum. In absence of any rigorous method, the afflux may be calculated by using Molesworth formula as given below:

$$h = (V^2/17.88 + 0.015) \times ((A/a)^2 - 1)$$

where:

h = afflux (in meters)

V = average velocity of the water in the river prior to constriction (in m/sec)

A = unobstructed sectional area of the river at proposed site (in sq. m)

a = constricted area of the river at proposed site (in sq. m)

**106.6.3** The effect of afflux on the velocity, submergence area and scour etc. shall be worked out and accounted for in the design.

## 106.7 Freeboard

**106.7.1** The freeboard for the approaches to high level bridges, where water spreads along the approaches, shall not be less than the minimum values specified in relevant IRC code for road designs. In case of canals and drain bunds, freeboard shall be provided as per requirements of Irrigation authorities.

**106.7.2** For the aggrading rivers in Himalayan foothills and flood-prone areas or North-Eastern States, North Bengal etc. and wherever required for some specific reason, the freeboard shall be suitably increased.

## 106.8 Vertical Clearance over HFL

**106.8.1** The vertical clearance shall ordinarily be provided as given in the following clauses.

**106.8.2** For openings of high-level bridges, which have a flat soffit or soffit with a very flat curve, the minimum clearance shall be in accordance with the following table. The minimum clearance shall be measured from the lowest point of the deck structure inclusive of main girder in the central half of the clear opening unless otherwise specified.

| Discharge in Cumecs | Minimum Vertical Clearance in mm |
|---|---|
| Upto 0.3 | 150 |
| Above 0.3 & upto 3.0 | 450 |
| Above 3.0 & upto 30.0 | 600 |
| Above 30.0 & upto 300 | 900 |
| Above 300 & upto 3000 | 1200 |
| Above 3000 | 1500 |

**106.8.3** For arched openings of high-level bridges having overhead decking, the clearance below the crown of the arch shall not be less than one tenth of the maximum depth of water plus one-third of the rise of the arch intrados.

**106.8.4** No part of the bearings shall be at a height less than 500 mm above the design highest flood level, taking into account afflux.

**106.8.5** In the case of artificial channels having controlled flows and carrying no floating debris, vertical clearances lesser than that specified in Clause 106.8.2 & 106.8.3 above may be provided.

**106.8.6** In the case of bridges in sub-mountainous region and across aggrading rivers, silting of the bed of the river should also be taken into consideration while fixing the vertical clearance.

**106.8.7** In case of bridges across tidal rivers, creeks, sea, the vertical clearance shall be provided keeping in view the HTL and normal wave / splash effects.

## 106.9 Determination of the Maximum Depth of Scour

**106.9.1** The probable maximum depth of scour to be taken for the purpose of designing foundations for piers, abutments and river training works shall be estimated after considering all local conditions over a reasonable period of time.

**106.9.2** Wherever possible, soundings for the purpose of determining the depth of scour shall be taken in the vicinity of the site proposed for the bridge. Such soundings are best taken during or immediately after a flood before the scour holes have had time to silt up appreciably. Allowance shall be made in the observed depth for increased scour resulting from:

i) The design discharge being greater than the flood discharge.

ii) The increase in velocity due to obstruction in flow caused by construction of the bridge.

iii) The increase in scour in the proximity of piers and guide bunds.

### 106.9.3 Scour

106.9.3.1 The following theoretical method may be adopted when dealing with the natural channels flowing over scourable beds for the estimation of mean depth of scour '$d_{sm}$' in meters below the Highest Flood Level (HFL).

$$d_{sm} = 1.34 \times \left[\frac{D_b^2}{K_{sf}}\right]^{1/3}$$

Where:

$D_b$ = The discharge in Cumecs per meter width. The value of "$D_b$" shall be the maximum of the following:

i) The total design discharge divided by lower of the effective linear waterway between abutments or guide bunds, and theoretical linear waterway.

ii) The value obtained taking into account any concentration of flow through a portion of the waterway assessed from the study of the cross-section of the river. Such modification of the value may not be deemed applicable to minor bridges of length upto 60 m.

iii) Actual observations, if any.

$K_{sf}$ = the silt factor for a representative sample of the bed materials obtained down to the maximum anticipated scour level and is given by the expression $1.76\sqrt{d_m}$ in case of sandy soils (having particle size between 0.04 mm to 2.00 mm), where "$d_m$" is the weighted mean diameter of the bed material in mm.

Clayey beds having weighted diameter less than 0.04 mm offers more resistance to scour than sand. In absence of any accepted rational formula or any data of scour atthe site of the proposed bridge, the following theoretical calculations may be adopted:

i) In case of soil having $\phi < 15^{o}$ and c (cohesion of soil) > 0.2 Kg/cm$^2$, '$K_{sf}$' shall be calculated as follows:

$K_{sf} = F(1+\sqrt{c})$, where 'c' is in Kg/cm$^2$

Where,

F = 1.50 for $\phi > 10^{o}$ and $< 15^{o}$

= 1.75 for $\phi > 5^{o}$ and $< 10^{o}$

= 2.00 for $\phi < 5^{o}$

ii) Soils having $\phi > 15^{o}$ will be treated as sandy soil even if 'c' is more than 0.2Kg/cm$^2$, and silt factor will be as per provision for sandy soil.

Notes:

i) The effective linear waterway shall be determined in accordance with Clause 106.5.3 and in no case shall exceed the value assessed as per Clause 106.5.1.2.

ii) A typical method of determining "$d_m$" is set forth in **Appendix-2**.

iii) The value of $K_{sf}$ to be adopted for the purpose of design should be determined after laboratory testing of the representative samples of bed materials collected during the sub-soil exploration.

106.9.3.2 If there is any predominant concentration of flow in any part of waterway due to bend of the stream in immediate upstream or downstream or for any other reason, like wide variation in type of bed material across the width of channel, then mean scour depth may be calculated dividing the waterway into compartments as per the concentration of flow.

106.9.3.3 Maximum scour depth

The maximum scour depth below the highest flood level (HFL) is considered for the purpose of design of foundations, protection works, river training works etc. For the design of piers and abutments having individual foundations without any floor protection, it shall be computed as below:

a) Flood without seismic combination

i) For piers = 2.0 $d_{sm}$

ii) For abutments (a) 1.27 $d_{sm}$ with approach retained or lowest bed level which ever is deeper.

(b) 2.00 $d_{sm}$ with scour all around

b) Flood with seismic combination

For considering load combination of flood and seismic loads (together with other appropriate combinations given elsewhere) the maximum depth of scour computed as per clause 106.9.3.3 (a) may be reduced by multiplying factor of 0.9.

For low water level (without flood conditions) combined with seismic combination maximum level of scour below high flood level can be assumed as 0.8 times scour computed as per clause 106.9.3.3(a).

c) In respect of viaduct / ROB having no possibility of scour, resistance of soil may be considered below depth of excavation for services construction, or 2.0 m below ground level which ever is greater.

d) For the design of floor protection works for raft or open foundations, the following values of maximum scour depth may be adopted:

| | |
|---|---|
| i) In a straight reach | 1 .27 $d_{sm}$ |
| ii) In a bend | 1.50 $d_{sm}$ or on the basis of concentration of flow |

The length of apron on upstream may be 0.7 times of the same on downstream.

e) Special studies should be undertaken for determining the maximum scour depth for the design of foundations in all situations where abnormal conditions, such as, the following are encountered:

i) A bridge being located on a bend of the river involving a curvilinear flow, or excessive shoal formation, or

ii) A bridge being located at a site where the deep channel in the river hugs toone side, or

iii) A bridge having very thick piers inducing heavy local scours, or

iv) where the obliquity of flow in the river is considerable, or

v) where a bridge is required to be constructed across a canal, or across a river downstream of storage works, with the possibility of the relatively clear water inducing greater scours, or

vi) A bridge in the vicinity of a dam, weir, barrage or other irrigation structures where concentration of flow, aggradation / degradation of bed, etc. are likely to affect the behavior of the structures.

vii) An additional two-lane bridge when located near to the existing bridge, on major rivers.

These studies shall be conducted for the increased discharge calculated vide Clause106.4.

106.9.3.4 If a river is of flashy nature and the bed does not lend itself readily to the scouring effect of floods, the formula for $d_{sm}$ given in the Clause 106.9.3.1 shall not apply. In such cases the maximum depth of scour shall be assessed from actual observations.

106.9.3.5 Gravel or Boulder beds

Bridge located across streams having gravel or boulder beds (normally having weighted diameter more than 2.00 mm), there is yet no rational formula for determining scour depth. However, the formula given in Clause 106.9.3.1 may be applied with the following silt factors, for particle size more than 2.00 mm.

| Bed Materials | Mean Size of Particle ($d_m$) | Silt Factor ($K_{sf}$) |
|---|---|---|
| Sand (Course) (2.0 mm to 4.75 mm) | 1.29 | 2.00 |
| Gravel (fine) (4.75 mm to 20 mm) | 5.16 | 4.00 |
| Gravel (Coarse) (20 to 80 mm) | 26.00 | 9.00 |
| Cobbles and Boulder (>80 mm) | 26.00 | 9.00 |

The results may be compared with actual observations at the site or from experiences on similar structure nearby and their performance and decisions taken on the basis of sound engineering judgement.

106.9.3.6 Obstruction in the channel bed, likely to divert the current or cause undue disturbed flow or scour and thereby endanger the safety of the bridge, shall be removed as far as practicable from within a distance upstream and downstream of the bridge not less than the length of the bridge subject to a minimum of 100 meters in each direction. Attention shall be given to river training and protection of banks over such lengths of the river as required. In case it is not possible to remove such obstructions, its effect on scour shall be considered.

## 106.10 River Training and Protection Works

**106.10.1** The slopes, in front of abutments and the portion of bridge approaches falling in the flood zone, shall be provided with suitably designed pitching and launching apron.

**106.10.2** In case of the uncertain and changing flow conditions, adequate river training works shall be provided for protection of banks, embankments and directing the river to flow under the bridge.

After collecting the required data, studying and analyzing the river flow conditions etc. and necessary model studies, wherever required, the protection works shall be designed as per provisions of IRC:89-2019 "Guidelines for Design and Construction of River Training & Control Works for Road Bridges (Second Revision)" or other specialist literature.

## 106.11 Hydraulic and Mathematical Model Studies

**106.11.1** ***These Studies should be carried out wherever necessary, such as:***

- in case of big rivers with large discharge having uncertain and complex flow conditions and for other abnormal situations
- when the linear waterway and scour cannot be accurately calculated or
- when the protection and river training works cannot be designed reliably because of the uncertain or complex conditions.

**106.11.2** The studies should be carried out at the reputed, reliable and accredited institutions only where requisite facilities are available.

**106.11.3** The Site and Contour surveys for these studies should be done very carefully, with precision and it should be ensured that these along with bed materials are correctly represented in the Model.

# 107 GENERAL DESIGN REQUIREMENTS

## 107.1 Structural System and Configuration

The structural scheme, structure type, span arrangement, member size and shape fora bridge shall be made after considering the following aspects:

a) Operations and Maintenance requirements

b) Design life and intended purpose of the bridge.

c) Structural requirements to withstand safely all applied loads as per IRC:6, desired strength, stability and safety and functional requirements like discharge, waterway and clearances.

d) Construction requirements like; available time for construction; availability & cost of local materials, labour, plants & equipment; availability of space for construction yard / site; availability of precast element factories and transportation and erection facilities; repeatability of structural elements; and requirements & possibility of traffic diversion etc.

e) Mitigation of adverse social and environmental impacts.

f) Durability and performance requirements during its design life.

g) Aesthetic requirements.

h) Future widening requirements.

i) Sustainability requirements like reduced carbon footprints and recyclability requirements, optimum use of materials, increased use of fly ash, blast furnace slag or other industrial by-products and recycled aggregates etc.

j) Requirements for accelerated bridge construction.

k) Encouraging use of Integral or Continuous bridges from consideration of riding comfort and long-term performance.

l) Curvature and skew angle.

m) Availability of funds.

n) Importance of the bridge and Strategic considerations.

o) Initial cost and Life cycle cost.

## 107.2 Bridge Foundation

Bridge foundation can be shallow or deep foundation type. The structural, hydraulic, and geotechnical aspects of foundation design shall be considered and coordinated during finalization

of the conceptual design and foundation type. Consideration shouldbe given to the following:

a) Interdependence of design, shape and size for foundation, substructure and superstructure

b) Type of sub-soil strata and its bearing strength.

c) Hydraulic and Hydrological considerations.

d) Constructability, construction approach and construction methods.

e) Effect and need of protection works on foundation design.

### 107.3 Bridge Substructure

a) Bridge Piers can be of various configurations such as wall, circular, trestleor any other shape with solid or hollow section.

b) Bridge abutments can be of various configurations such as spill-through type and non-spill through type with solid wall, counterfort wall, box type or bank seat type.

### 107.4 Bridge Superstructure

The superstructure type shall be as per Clause 102.3. The choice of superstructure would largely depend upon the functional, aesthetic and techno-economic criteria, suited to the location of the bridge.

### 107.5 Retaining Walls

Wing walls for a bridge can be splayed type, at an angle to the bridge axis or return wall type, parallel to the bridge axis or it can be cantilever type projecting out of the abutment. Reinforced Soil walls or Gabion walls can also be provided as per the site conditions.

### 107.6 Pipe Culverts

Reinforced concrete and prestressed concrete pipes for culverts and bridge structures shall be of Non-Pressure (NP) - 4 type conforming to the requirements of IS:458 and IS:784 with minimum nominal internal diameter of 1200 mm.

## 108 CONSTRUCTION AND CONSTRUCTABILITY CONSIDERATIONS

### 108.1 Constructability Considerations

Constructability considerations aim at optimum use of required construction knowledge and experience in planning, design, procurement, and field operations, to achieve overall project objectives. Constructability drives consideration of the entire construction process during the conceptual design stage. Dimension and reinforcement of components in a bridge, many a times are dictated by the construction and erection phase requirements rather than the service stage requirements. The design therefore must consider various factors, which influence the constructability of the bridge. A typical check list of factors is given below:

a) Access to work areas and remote areas,

b) Access to emergency vehicles and routine maintenance of site,

c) Availability of land for plant / equipment and machinery,
d) Availability of required and alternative materials,
e) Simplicity of design & clarity in detailing,
f) Ease of fabrication of steel members,
g) Standardization of design elements to the extent possible,
h) Weather conditions and working periods,
i) Conflicts with existing traffic,
j) Conflict with services and utilities,
k) Availability of skilled manpower,
l) Social and Environmental issues,
m) Region e.g. mountainous, proximity to sea, desert, marine clay etc.,
n) Height above Water Level / Ground Level,
o) Availability of suitable casting yard and storage of precast elements.

## 108.2 Construction Considerations

**108.2.1.** Bridge construction involves managing the entire logistics of construction, including construction operations of both permanent as well as temporary works that are needed for safe and efficient building of the structures. Efficient construction would require appropriate knowledge and experience in planning, design, detailing, procurement of materials and plant and equipment, besides site operations to achieve overall project objectives. Construction shall be carried out by personnel having appropriate skills to ensure quality as envisaged. Adequate supervision and quality control shall be provided during all stages of construction.

**108.2.2.** The design process must include the necessary detailing and construction knowledge and experience to realize the full potential of construction benefits without compromising the integrity of structure or design consideration. The choice of structural system and the design and detailing of the structure therefore shall be made by appropriately qualified and experienced persons having thorough knowledge of design and construction. For many bridges, the design is construction driven, in which case construction methodology as considered in design must be reflected in the design drawings and be implemented. In case methodology of construction is required to be changed during implementation, due to any unforeseen reasons, its impact on design must be investigated and accounted for before carrying out construction.

**108.2.3.** Suitable materials and methodology of construction including use of suitable specialized equipment shall be adopted for completion of bridge within the given timeframe.

**108.2.4.** Design shall consider the method of construction which will be carried out through project management, involving, planning, scheduling and controlling including safety, in accordance with a work program which is required to be prepared for each bridge project.

i) Planning commences with the analysis of the type and scope of work to accomplish the task as well as the specifications for the work, construction methods, materials, equipment and manpower.

ii) Scheduling establishes a sequence of operations and accounts for inter relation of operations at the job site as well as allocation of manpower, material and equipment.

iii) Controlling consists of procuring materials as per construction sequence and stage, dictating overall construction procedures, inspection and test procedure and maintaining complete records of daily progress etc. In order to ensure proper quality of work, a suitable quality plan needs to be developed before taking up construction.

iv) Safety during construction will include safety of various operations encompassing the safety of works, work personnel, equipment as well as traffic in the work zone.

## 108.3 Construction Approach

**108.3.1** Bridges can be designed and constructed either on the basis of conventional approach or Accelerated Bridge Construction approach. Both approaches are equally applicable for new construction of bridges and replacement or rehabilitation of the existing bridges.

**108.3.2** Accelerated Bridge Construction (ABC) is defined as type of the bridge construction that uses innovative project planning, design, innovative materials, smarter procurement, and construction methods or techniques in a safe and cost-effective manner to significantly reduce construction and mobility related impacts by reducing the number of onsite construction days and / or minimizing traffic disruption. ABC approach is basically aimed at:

a) reducing the onsite construction time and project schedule,

b) reducing the weather-related time delays,

c) minimizing the traffic or mobility impacts (increased work-zone safety for the public or minimized traffic delays / lane closures / disruptions - lesser disruption to local economy or reducing the amount of disruption to surrounding areas during construction) and social costs,

d) Improving the constructability,

e) Encouraging the utilization of innovative planning, design, new materials, and construction methods as alternative to conventional approach in order to meet challenging project goals that would be difficult or impossible to achieve with conventional construction methods,

f) constructing the projects falling in the regions having limited working period on account of seasonal, environmental, or economic restrictions or the projects requiring long detours,

g) reducing the congestion, air and noise pollution in urban and mountainous areas,

h) avoiding and minimizing the environmental impacts, and

i) resulting in reduced life-cycle costs and project costs.

**108.3.3** ABC needs to be considered for all new and rehabilitation of distressed bridge projects and should be adopted for achieving project goals

**108.3.4** Taking into consideration of how the bridge is being constructed, ABC uses a variety of tools to accelerate scheduling, minimize risk, and improve efficiencies, including innovative materials and specifications, fabrication and erection of bridge elements, alternative procurement methods, creativestaging and traffic control, the use of incentive / disincentive provisions, and cost-plus-time-based bids. Other common and equally viable reasons to use ABC is to deal with site constructability issues. Oftentimes long detours, costly use of a temporary structure, remote site locations, and limited construction periods present opportunities where the use of ABC methods can provide more practical and economical solutions compared to those offered if conventional construction methods were used.

## 108.4 Construction Methods

For chosen type of superstructure system, the analysis and design of a bridge depends on the sequence and method of construction as well as erection methods. The basic construction method may be cast-in-situ, precast or prefabricated either onsite or offsite, segmental, cantilever or balanced cantilever, and incremental launching. Combination of one or more basic methods are usually adopted. Erection method and equipment as well as supporting mechanism / approach have also brought variations in construction methods. The selection of construction methods is primarily based on the bridge site conditions, function, structural and economic considerations. In general, the construction method and technique may be selected after considering the following aspects besides those given under clause 108.1 and clause 108.2:

i) chosen system and structural form of the superstructure and supporting element(s),
ii) available time for construction, available working season, and weather conditions during construction stage,
iii) available space at construction site,
iv) numbers, size and weight of precast elements and their repeatability,
v) ease of constructability,
vi) construction of structural elements at site or offsite (away from the site)or combination of onsite and offsite,
vii) available facility of erection, erection equipment, erection method and capacity as well as suitability of erection method to site,
viii) available lift facility and capacity as well as its feasibility to suit site requirements,
ix) availability / requirements of logistics including transportation and handling facility,
x) type of the material and available sources,
xi) available expertise and experience of the contractor,
xii) impacts on traffic mobility and safety of the traffic,
xiii) impacts to surroundings,
xiv) construction and maintenance costs.

# 109 AUXILIARY COMPONENTS

## 109.1 Provision for Utilities

**109.1.1** A bridge structure shall cater for fixtures for electric posts, lamp posts and suitable ducts for carrying electric cables etc. as required to cater for utility services.

**109.1.2** Utility services like cables and pipelines for water, gas, petroleum products directly on bridge structure should be avoided. These may be placed on a structure supported on piers and abutments.

**109.1.3** While planning, there is need for proper accessibility of the services utilities for inspection and maintenance without hindrance to traffic movements.

## 109.2 Drainage

### 109.2.1 *General*

The bridge deck and its immediate highway approaches shall be designed to provide safe and efficient conveyance of surface run-off, in a manner that causes minimum damage to the bridge and ensures safety of the passing vehicle. Transverse drainage is achieved by providing a suitable camber or super elevation,sufficient for positive drainage.

### 109.2.2 *Bridge Deck Drainage*

Drainage spouts shall be provided at suitable spacing, depending upon the width of carriageway, to drain off the water from the carriageway during rains. For deck width less than 3 lanes, the minimum internal diameter of drainage spout shall be 150 mm and maximum spacing shall be 10 m. The spouts shall be robust to withstand damage during cleaning and shall be of corrosion resistant material such as galvanized steel with suitable cleanout fixtures. For wider carriageways having width more than 3 lanes m in each direction of traffic, special design of deck drainage may be needed to reduce the potential for hydroplaning

The underside of the outside edge of bridges shall be designed with continuous drip grooves to prevent staining of the surface. In the case of bridges across a stream or a river, the rain water can discharge into the river bed through drainage spouts provided at suitable spacing. The surface drainage collected at deck drain locations shall be directed through the superstructure by individual vertical or near-vertical down-take pipes or downspouts.

In situations, where it is not possible to discharge into the underlying water course, consideration should be given to conveying the water in a longitudinal storm drain affixed to the underside of the bridge and discharging it into appropriate facilities onnatural ground at bridge ends.

Runoff from the bridge deck at the abutments shall be intercepted either immediately beyond the end of the bridge approach slab or before the end of the curb or barrier, by catch basins or other suitable means. The water so intercepted shall be directed past the embankment slopes and abutments in order to control embankment erosion.

Discharge from deck drains shall be channeled and shall be kept away from the deck structure and abutments by means of suitable down-take pipes and downspouts to locations that can be protected from erosion and provided up to 500 mm above High Flood Level or drains at ground level. Down-take pipes, wherever provided, shall be of a rigid corrosion-resistant material. Down–take pipe systems shall be designed so that water is not discharged onto the traffic or facilities below the deck, such as roadways or pedestrian paths. Changes in direction in down-take pipes

shall be not greater than 45°. Cleanouts shall be provided near bends or at intervals to permit access to all parts of a downpipe system.

### 109.2.3 *Storm Water Drainage Design*

The design of the drainage system involves:

a) Estimation of the run-off flow rate using rational method &

b) Fixing the slope and dimension of the drain to have adequate capacity to carry the discharge and afford proper maintenance.

Reference shall be made to special literature / IRC code for design.

### 109.2.4 *Drainage at the Foot of Flyovers*

Due to the longitudinal slope of ramp of a flyover, there is a tendency for the rain water to flow in longitudinal direction rather than in cross direction resulting in very large quantity of water reaching the valley curve area where it meets the ground level road. Suitable system of drainage shall be adopted to avoid ponding in such cases.

### 109.2.5 *Drainage for Underpasses*

For underpasses, the possibility of designing the storm water drainage based on gravity flow shall be the first choice. In case the surrounding levels do not permit a gravity-based system of drainage, suitable arrangement for pumping out the water shall be provided.

## 109.3 Bearings

### 109.3.1 *General*

a) Bearing is provided to transfer vertical and / or lateral loads from superstructure to substructure as well as to allow desired levels of movements of the superstructure. Appropriate type and arrangement of bearings shall be selected on the basis of geometry and type of superstructure, nature and magnitude of vertical and horizontal loads and direction and magnitude of rotational and translational movements.
Bearing system shall be designed to ensure stability of the superstructure and desired performance of the structure as a whole.

b) It shall be easy for installation and inspection.

c) Bearings shall be robust and durable.

d) Provision shall be made for replacement of bearings, since the design life of bearings is less than the design life of a bridge.

e) Materials for bearings are generally, elastomer, steel and PTFE or their combination.

f) Bearings may not be provided for spans upto 10 m. In such cases, separation layer of paper impregnated with bitumen or equivalent may be provided between superstructure and substructure.

**109.3.2** Bearings shall be designed and installed as per relevant IRC:83 (all Parts) and Ministry of Road Transport and Highways, MoRTH Specifications for Road and Bridge Works.

## 109.4 Expansion Joints

### 109.4.1 *General Features*

a) The expansion joints shall cater for expected movements and rotation of the structure at the joints and provide smooth riding surface.

b) It shall also be easy for inspection and maintenance.

c) Expansion joints shall be robust, durable, water-tight and replaceable.

d) The expansion joint shall be provided and designed as per relevant IRC Publications.

## 109.5 Wearing Coat and Waterproofing layer on the deck

Wearing Coat over deck of bridge superstructure shall be either bituminous wearing coat or concrete wearing coat, along with a water proofing layer underneath or above to make it impermeable. Concrete wearing coat along with water proofing layer may be provided in case of bridges located in remote areas and in situations where accumulation of water is expected (e.g. in underpasses).

## 109.6 Crash Barriers

### 109.6.1 *Suitably* Designed *Crash Barriers shall generally be located on:*

a) All high-level bridges, flyovers, interchanges and ROB's.

b) Approaches to bridge structure, reinforced soil walls, return walls and where height of embankment is more than 3 m.

c) High containment crash barrier shall be provided on ROBs, complex interchanges (multi-level interchanges, Interchanges with loops and sharp radii less than 100 m), bridges and flyovers on sharp radius less than 100 m and other similar hazardous and high-risk locations (such as grade separators with heavy intensity of traffic passing below and where design speed is more than 80 KMPH, overpass structures etc.)

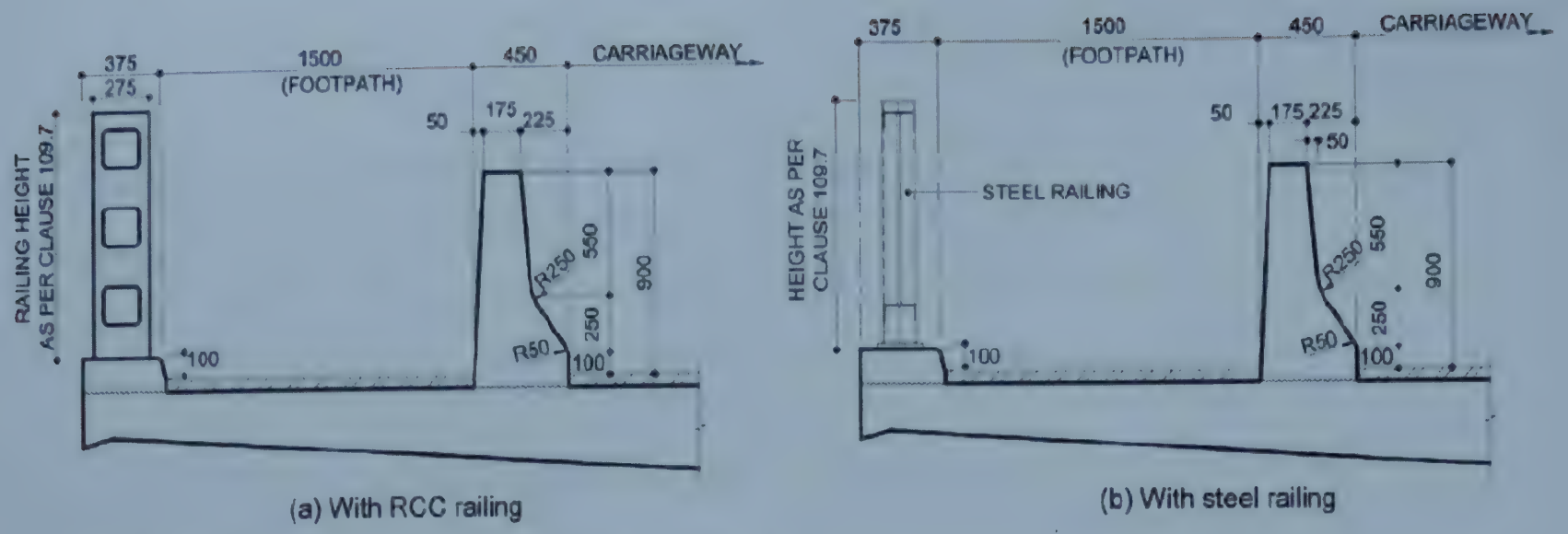
### 109.6.2 *The Crash Barrier shall be of the following types:*

a) **Flexible Barrier**: These are yielding type such as wire rope fencing.

b) **Semi-Rigid Barrier**: These offer required resistance to errant vehicles by deflection of the longitudinal member to an acceptance limit (e.g. metal beam crash barriers).

c) **Rigid Barrier**: these do not deflect on impact and hence take full severity of impact (e.g. reinforced concrete crash barrier).

**109.6.3** Typical shapes and dimensional details of crash barriers and their locations on the bridge decks with or without footpaths are shown in **Fig. 1 to 5.** These may be suitably modified and augmented depending on the developments in design and future functional requirements in individual cases. Design shall conform to relevant IRC standards and specialist literature.




(a) With RCC railing

(b) With steel railing

**Fig.1 Details of Concrete Crash Barrier & Railing for showing Bridge with Footpath**

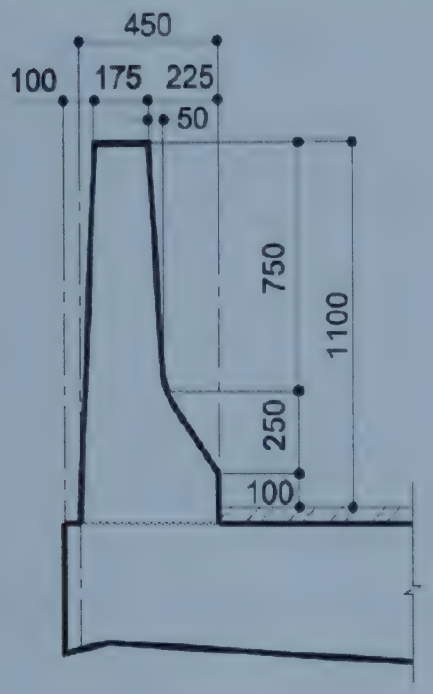



**Fig.2 Details of Crash Barrier for Bridges without Footpath**

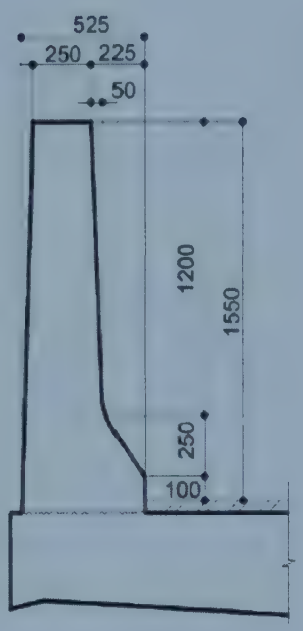
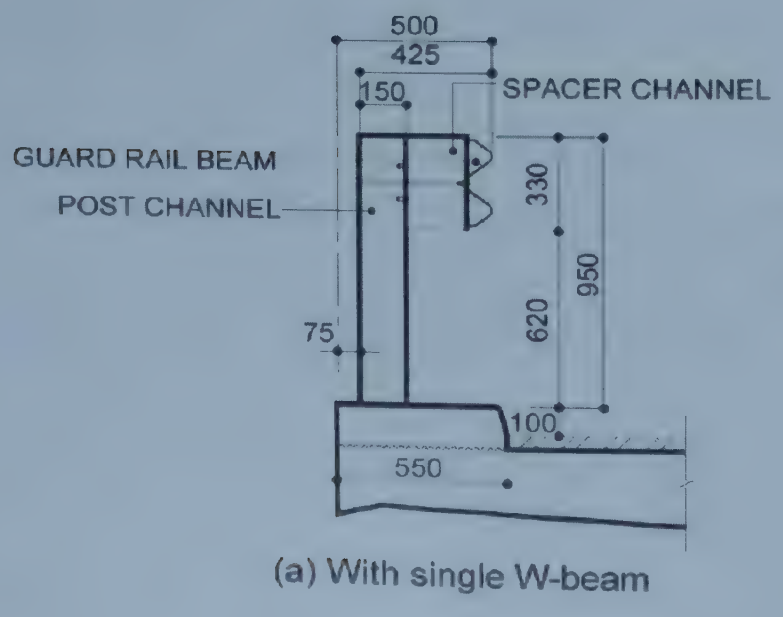



**Fig.3 Details of High Containment Crash Barrier**




(a) With single W-beam

(b) With double W-beam

**Fig.4 Details of Metallic Crash Barrier**

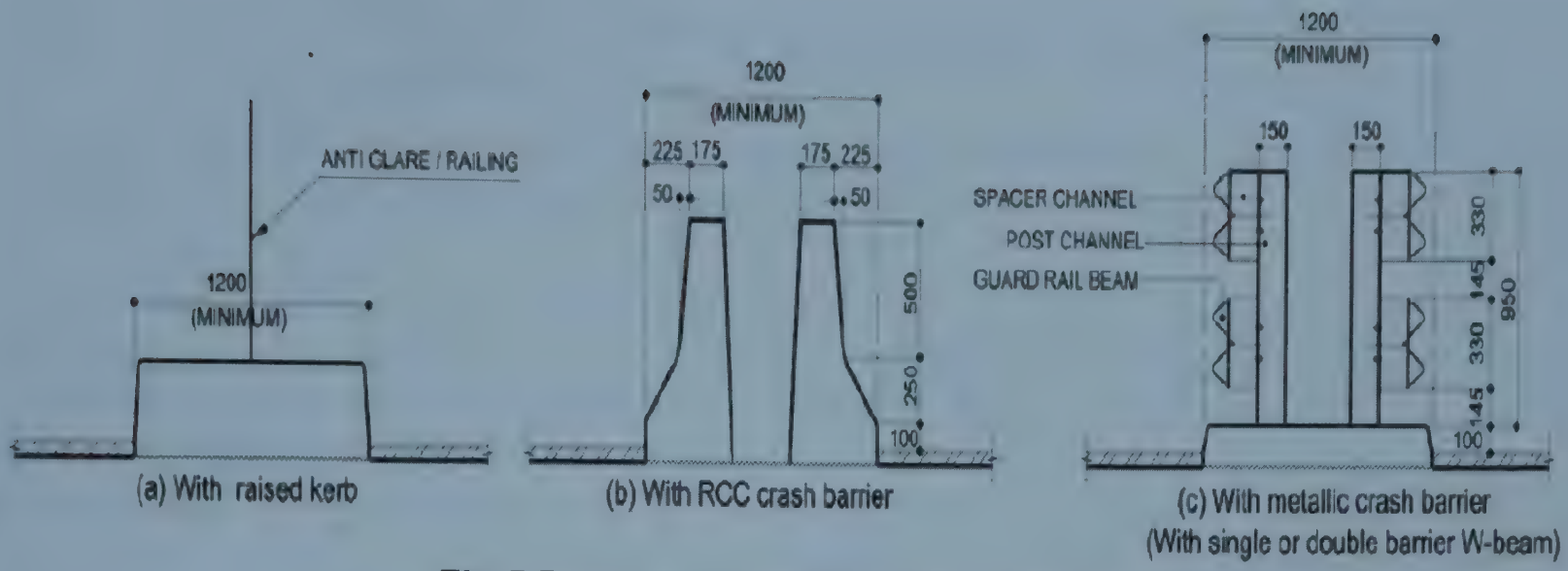



**Fig.5 Details of Crash Barrier in Medians**

**109.6.4** Flexible and semi rigid barriers shall not be provided on bridges without footpath on outer side of the carriageway.

## 109.7 Railings, Parapets and Guideposts

### 109.7.1 *General Features*

a) The bridge railings or parapets shall include the portion of the structure erected on and above the kerb / deck for the protection of pedestrians or cyclists.

b) Railing or parapet may be of the following type:

- Steel rolled section
- Tubular steel
- Cast-in-situ concrete
- Pre-cast concrete

c) The railing or parapet should be fixed and placed to correct alignment and camber throughout their length to ensure proper form, line and level.

d) Proper contraction / expansion gaps, compatible with main supporting structure shall be provided in railing or parapet, to ensure that they function properly.

e) The railing or parapet should be designed for loads and forces as per relevant IRC codes.

### 109.7.2 *Railings for High Level Bridges, Flyovers, Interchanges and ROBs*

109.7.2.1 Substantial railing or parapets along each side of the bridge shall be provided for the protection of pedestrians or cyclists from falling over. Railings or parapets should be avoided for protection of vehicular traffic except in case of small bridges or culverts.

109.7.2.2 Importance shall be given to the architectural features of the railing or parapet to obtain proper proportioning of its various members and its harmony with the structure and the environment as a whole.

109.7.2.3 Railings or parapets shall have a minimum 1.1 meter height above the adjacent roadway or footway safety kerb surface. For bridges exceeding 300 meters in length, the height of

railings, determined in the manner stipulated above, shall be increased by 0.1 meter. For ROBs across railway lines, the height shall be governed by Railway's requirements.

109.7.2.4 Where a road provided with cycle tracks, is carried on a bridge and the cycle track is located adjacent to the bridge railing or parapet, the height of the railing or parapet shall be minimum 1.25 meters.

109.7.2.5 The clear distance between the bottom most rail and the top of the kerb shall not exceed 150 mm unless the space is filled by vertical or inclined members, the clear distance between which is not more than 150 mm, The strength of the bottom most rail shall be at least as much as that of the top rail. The space between the bottom most rail and the top rail shall be filled by means of vertical, horizontal or inclined members, the clear distance between which shall be fixed with due regard to the safety of those using the structure.

109.7.2.6 Guard rail shall be provided at the high approaches. The design, layout and materials chosen for the rails shall suitably blend with the surroundings.

### 109.7.3 *Railings for Submersible Bridges and Vented Causeway*

109.7.3.1 Railing shall be either collapsible or removable.

109.7.3.2 Collapsible railing shall be installed where the bridge is to be opened to traffic soon after a submerging flood has receded. Care shall be taken in the structural design of these railings to ensure that they sit well in their grooves and are not liable to displacement by floods.

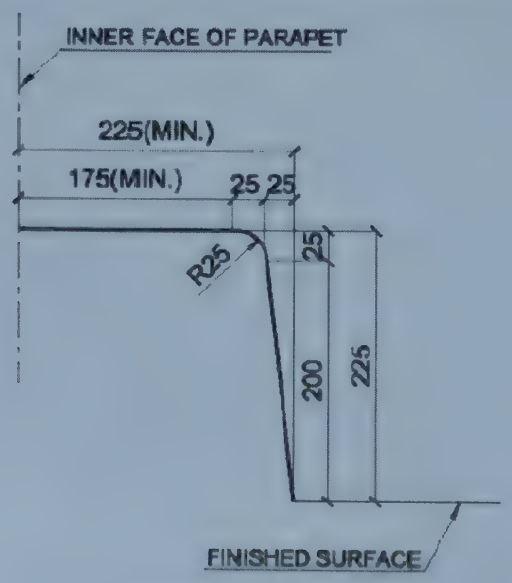
109.7.3.3 Removable type of railings may be adopted when there is no danger to the traffic using the bridge for short periods without railings. Care shall be taken in the structural design of these railings to ensure that the various members are interchangeable and can be easily removed and refitted.

109.7.3.4 Collapsible or removable railings shall be designed to resist the same forces as specified in relevant IRC codes for railings or parapets on high level bridges.

109.7.3.5 Guideposts / stones may be used in lieu of railings, if the submergence of the road surface over the causeway is frequent and use of removable or collapsible railings becomes unsatisfactory.

## 109.8 Kerbs

**109.8.1** The section given below shall be generally adopted for surmountable road kerbs. In case of unsurmountable road kerbs the section shown shall be suitably modified.




OUTLINE OF ROAD KERB
(All Dimensions are in Millimeters)

**109.8.2** The section of the kerb should be so designed that it would be safe for vertical and horizontal loads as per relevant IRC Codes.

**109.8.3** A safety kerb will have the same outline as that of a road kerb, except that the top width shall not be less than 750 mm.

### 109.9 Noise Barriers

To mitigate the impact of excessive noise generated by road traffic at select sensitive locations (e.g., near hospitals, academic institutions etc.), suitable type of noise barriers with proper design may be provided, as per IRC: SP:130.

### 109.10 Numbering of Bridges and Culverts

Suitable Number Plates shall be provided on bridges and culverts as per IRC-7 for their identification

## 110 ILLUMINATION

**110.1** All bridges should have provision for illumination. Provision for cabling, mounting and installation of luminaries shall be considered in design and detailing. Support system provided for the bridge lighting shall be adequately designed for the expected loadings. The support system shall be detailed so that it does not sacrifice the kerb and crash barrier running profile, maintaining its continuity. The support system, mountings and other fixtures required for illumination of the bridge shall not impair the functionality of other road furniture.

**110.2** Illumination plan for bridges, grade separators, under-passes and interchanges shall be considered during initial planning. The arrangement of the masts / poles i.e. its height and spacing, should be such as to achieve the minimum level of illumination $E_{min}$=40 Lux.

Overall Uniformity Ratio, $E_{min}/E_{av}$ shall not be less than 0.4, where $E_{min}$ is the minimum luminance in the area and $E_{avg}$ is the average illuminance in the area.

Maintenance factor, which is the ratio of average illumination on the working area, given by an installation with decreased effectiveness due to dust, pollution, line voltage drop, ageing of lamp, product tolerance etc., to that of a new installation shall be considered as 0.75

**110.3** While deciding the illumination plan, consideration shall be given to energy efficiency, environmental pollution, aesthetic and economical aspects. The selection of lighting system and the layout should add to the overall aesthetic of the bridge.

**110.4** The installation, lighting arrangement, method of control, switches etc. shall conform to the provision contained in IS: 1944.

**110.5** Adequate lighting shall be provided at specific locations, such as loops, ramps, signal free interchanges, merging zones, rotaries, pedestrian crossing etc. Ramps and approaches should be lit to the same level as main lanes.

**110.6** At highway interchanges, different lighting arrangements, viz. lighting Poles or high masts or combination of both, may be considered and the one which gives optimum results from the viewpoint of aesthetics, safety, illumination and ease of maintenance may be adopted.

**110.7** Illumination levels for the vehicular and pedestrian subways / underpasses may be kept the same as those on the approaches at either end of the subway / underpass.

**110.8** At night, the level of luminance in a subway / underpass, should be constant and equivalent to the level on the road leading into the subway / underpass. However, since there is a high level of external light during the day, it is necessary to increase the level of luminance at the entrance of the subways / underpasses, mainly to avoid a black hole effect leading to a reduction in visual perception. At the exit of subways / underpasses, the level of luminance should also be increased to avoid drivers being subjected to glare effects by the light outside. Thus the illumination layout of a subway / underpass shall be planned considering the various zones (viz. Threshold, Transition, Interior and Exit zones). A symmetric or pro-beam lighting systems shall be used except in the transition zone where it may be counter beam type.

Wherever feasible the vehicular / pedestrian / cattle underpasses in remote areas should have provision of skylight to get the light inside underpass during the day.

## 111 ROAD SIGNS AND SIGNALS

Appropriate plan for road markings, signage, delineation and signals (where necessary) shall be made and integrated with the overall bridge planning. These should be provided on bridges, flyovers grade separators and their approaches to facilitate smooth and safe movement / operation of traffic without creating any confusion among users and also to minimize the possibilities of serious damage to the bridge structure or any of its components in the event of accidents. Provisions should be made in the structures for supporting of signals, signages and delineators.

### 111.1 Road Markings

a) The road marking symbols, patterns, sizes, colour and legends shall be adopted in accordance with IRC:35 Code of Practice for Road Marking.

b) Where the number of lanes on the bridge and on approaches are different (e.g. a two lane bridge on a three lane approach or vice versa), a transition taper should be given. The excess carriageway width in the transition zone should be appropriately chevron or diagonal hatch marked to ensure that it does not form part of the travelled way. There should be a corresponding sign as well to indicate narrowing or widening of carriageway.

c) Hazard markers and / or crash cushions shall be provided at beginning of median or crash barrier clearly indicating start of a bridge / flyover or loop emerging from main carriageway. Hazard marker shall be provided at such locations with or without crash cushion.

d) Chevron Markings / Painted Islands shall be provided at all exits to slip roads from main highway before a bridge / flyover or vice versa.

### 111.2 Signals

a) Signals, near or on the bridges, shall be provided as per specific requirement of the any particular project, conforming to the requirements of IRC:93.

b) Signals can be either electrically operated or solar powered.

c) Flashing beacons shall be provided at the beginning of median or crash barrier, clearly indicating start of a bridge / flyover or loop emerging from main carriageway. Provision of cables for power supply to any such signal shall be considered in addition to the regular illumination.

### 111.3 Road Signs

a) All multi-lane bridges, complex interchanges and grade separated structures shall be provided with overhead signs, well in advance and, if required, on the structure, conforming to the provision specified in IRC:67. Only retro-reflective signs shall be permitted. Non-Luminous signs shall not be permitted.

b) The location of sign board, barrier kerbs and supporting system should be designed and planned along with the project and detail of the scheme shown in a drawing drawn to a scale of 1:500.

c) Support system for signs and signals required on bridge decks shall preferably be placed behind rigid type crash barriers. The sign supports shall be structurally safe and properly anchored to the bridge deck. The bridge deck shall be designed to withstand all such loads.

d) Wherever signs are to be illuminated or signals to be operated, necessary arrangements shall be made for cable ducts.

### 111.4 Delineators

Delineators (also referred to as guideposts) shall be provided as per safety requirements. These shall be installed along the side of the roadway in a series to indicate the alignment of the roadway. Delineators are particularly beneficial at locations where the alignment might be confusing or unexpected, such as at lane reduction, transitions and curves.

Delineators on structure portion shall be sticker-type mounted on crash barriers.

### 111.5 Distance Markers

For bridges, distance markers over crash barriers shall be provided suitably.

## 112 AESTHETICS

**112.1** Bridges have large visual impacts on their surroundings. To achieve aesthetically pleasing view of bridge and its surroundings, it is essential that attention should be paid to produce a clear, simple, well-proportioned structure form, blending harmoniously with its surroundings. Larger the length of a bridge, greater is its visual impact. Therefore, specialists in architecture and landscaping may be engaged for bridges having lengths of 500 m or more.

**112.2** Bridges should complement their surroundings, be graceful in form and present an appearance of adequate strength. Bridge designers must therefore consider appearance as an important design consideration. Attention should be given to appearance while looking towards the bridge as well as that while moving on the bridge.

**112.3** The visual appeal of the bridge can be attributed to its form, texture, colors and other details. Every visible component of a bridge has a role to play. Aesthetics of a bridge must be considered both in the conceptual planning stage as well as in the detailed design stage.

## 112.4 Considerations at Conceptual Planning Stage of a Bridge

Geometry, layout and concept are major determinants of appearance and should be addressed at the initial stages of a project. Following points shall be given due consideration at the conceptual stage of the project:

### 112.4.1 *Simplicity*

Generally, bridges seem aesthetically more pleasing if they are simple in form, superstructure are sleek in proportion to their spans, the lines of the structure are continuous and the shapes / sizes of the structural members reflect the flow of forces.

### 112.4.2 *Dimensions and Proportions*

Dimensions of various elements should generally develop harmony with the surrounding landscape and environment.

### 112.4.3 *Symmetry* of Structure

Symmetrical bridges are often more aesthetically pleasing than non-symmetrical bridges except in specific cases.

### 112.4.4 *Order and Rhythm*

Developing a rhythm in a bridge is also important. The cumulative effect of all bridge elements including lighting poles, barrier supports and piers should be considered.

### 112.4.5 *Unity of Design*

Various elements viz. parapets, safety barriers, light poles, deck, pier, approaches, immediate landscape and all the associated signage etc. are integral elements of the whole bridge design and should be considered in unison.

### 112.4.6 *Form or Appearance in Totality*

Visual forms of bridges, viaducts or flyover structures etc. should be selected with care to be in harmony with the general landscape and local architecture.

## 112.5 Considerations at Design Stage of a Bridge

The following points shall be given due consideration with respect to various components during design stage. This section deals with the basic elements that form a bridge structure. It deals with each element as a separate component. However, the designer must never lose sight of how each unit fits into the overall expression that is desired.

### 112.5.1 *Parapet*

The outer face of the parapet can be one of the most important aesthetic elements of a pleasing bridge and often the most dominant in long distance views. The top of the parapet

should slope towards the road, to channel rainwater onto the bridge, minimizing staining of the outside face. Treatment of fascia elevation by using serrations (grooves) / physical breaks or by changing relative brightness using surface slopes can make the bridge look slender than it really is. If the deck soffit is visually complex, consideration may also be given to hiding this complexity, by extending the parapet soffit below the deck soffit.

### 112.5.2 *Girder Elevation*

Haunched girders are expressive and responsive to the forces in the bridge. They can often be more distinctive and elegant than single depth beams. Abrupt changes in depth of superstructure should be avoided and be made gradual with flowing lines.

### 112.5.3 *Girder Cross Section*

The major visual design goals of the Superstructure are: apparent slenderness, continuity of lines and relationship with the substructure. The cross-sectional shape of the girder should be considered keeping in view the effect of light, shade and texture.

### 112.5.4 *Scale and Proportions*

The structure should be in scale with its surroundings as well as with other parts of the structure. The primary structural elements, e.g., span lengths, girder depth, pier and abutment heights, should have good proportional relationships to each other and their structural chore. Generally, no single element should dominate the visual composition. The collective design of the structure should be in scale with the site and environmental considerations. The structure form should have an appearance of lightness.

### 112.5.5 *Pier Cross Section*

Pier shapes will be largely influenced by the span arrangement, width of superstructure, height of piers and the nature of surroundings. When bottom section of pier is influenced by ground level conditions (e.g. median verge of a flyover) special shapes varying along height should be considered.

### 112.5.6 *Pier Caps*

Pier cap width and length are influenced by functional considerations but its visual integration with the pier below and deck above must receive the due attention

### 112.5.7 *Abutments*

In an open landscape setting, spill through or bank seat abutments are generally preferable, as walled abutment structures can block views. If unavoidable the use of planting should be considered to hide the abutment walls.

**112.5.8** The space around and under the bridge must be given due consideration as aesthetic success of the bridge depends a lot upon the beauty of its surroundings.

**112.6** Standard details when used need to be reviewed for their appropriateness to each project. They should be regularly updated.

**112.7** New bridges generally become part of a family of other bridges along a route. The impact and relationship to this family should be considered. The new bridge should respect the role, form and design of the existing parallel bridge.

## 113 OPERATION & MAINTENANCE

A structure will properly serve its intended design life only when it is regularly inspected and maintained in accordance with the IRC codes and guidelines.

Proper attention shall be given to ensure all critical components of the structure can be properly accessed and inspected. Therefore, proper Access / Arrangement for inspection of bearings, anchors, interior of box girders and the like should be thought of at design stage. Bearing Replacement scheme, where applicable, shall be planned at design stage and corresponding forces should be considered while designing various components of the bridge.

A maintenance manual shall be prepared for the bridge project.

Exposed parts of steel structures shall be accessible for inspection and periodic painting. Design documentation shall include indicative procedures for replacement as well as repair of bridge components like bearings, corroded anchors, expansion joints, drainage spouts etc.

Reference may be made to the relevant IRC codes for guidance on inspection and maintenance of road bridges.

## APPENDIX- 1

*(Clause 106.3.1.5)*

# UNIT HYDROGRAPH METHOD

The Unit Hydrograph, frequently termed as the unit graph, is defined as the hydrograph of storm run-off at a given point in a river, resulting from an isolated rainfall of unit duration occurring uniformly over the catchment and producing a unit run-off. The unit run-off adopted is 1 cm depth over a catchment area.

The term "Unit-Rainfall Duration" is the duration of rainfall excess resulting in the unit hydrograph. Usually, unit hydrographs are derived for specified unit durations, say, 6 hours, 12 hours etc., and derived unit hydrographs for durations other than these are converted into unit hydrographs of the above unit durations. The duration selected should not exceed the period during which the storm is assumed to be approximately uniform in intensity over various parts of the catchment. A 6 hours unit duration is suitable and convenient for studies relating to catchments larger than 250 sq.km.

The unit hydrograph represents the integrated effects of all constants of a basin, viz., drainage area, shape, stream pattern, channel capacities, stream and land slopes.

The derivation and application of the unit hydrograph is based on the following principles:

1) All the characteristics of the catchment of a river a reflected in the shape of the hydrograph of run-off.
2) At a given point on a river for all storms having the same duration of rainfall excess above this point and uniformly distributed with respect to time, the discharge ordinates of the hydrograph are proportional to the total volumes of storm run-off. This implies that rainfall excess of, say 2 cm, within the unit of duration will produce a run-off hydrograph having ordinates twice as great as those of the unit hydrograph. Also, if individual hydrographs are obtained from separate periods of uniform rainfall excess that may occur throughout a storm period, and these are properly arranged with respect to time, the ordinates of the individual hydrographs can be added to give ordinates representing the total storm run-off hydrograph for the entire storm period.

Three methods are generally available for giving unit hydrographs at any point in ariver.

a) By analysis of rainfall and run-off records for isolated unit storms;
b) By analysis of run-off compound hydrographs;
c) By computation of synthetic unit hydrographs, when sufficient rainfall and run-off data are not available.

The determination of design flood, after the unit hydrograph has been derived, involves the following steps:

a) Division of catchment into sub-areas, if necessary.

b) Derivation of design storm and its apportionment to sub-area.

c) Determination of minimum retention rate and calculation of rainfall excess of design storm.

d) Arrangement of design storm

e) Application of rainfall excess to unit hydrographs for each sub-area.

f) Routing of flood for each sub-area to the point of collection of the whole catchment.

A rational determination of critical design storm for a catchment requires a comprehensive study of major storms recorded in the region and an evaluation of effects of local conditions upon rainfall rate. This is particularly necessary in the case of design storms, covering a large area of several thousand square kms.

In the case of areas less than a few thousand square kms, certain assumptions can be made regarding rainfall patterns and intensity variations without being inconsistent with meteorological causes. They simplify design-storm estimation, but would entail high degree of conservation.

## APPENDIX- 1(a)

*(Clause 106.3.2)*

## REPORTS BROUGHT OUT BY CENTRAL WATER COMMISSION

### UNDER LONG TERM PLAN

| Sl. No. | Name of Sub-Zone | Sub-Zone No. |
|---|---|---|
| 1. | Luni sub-zone | 1(a) |
| 2. | Chambal sub-zone | 1(b) |
| 3. | Betwa sub-zone | 1(c) |
| 4. | Sone sub-zone | 1(d) |
| 5. | Upper Indo-Ganga Plains sub-zone | 1(e) |
| 6. | Middle Ganga Plains sub-zone | 1(f) |
| 7. | Lower Gangetic Plains sub-zone | 1(g) |
| 8. | North Brahmaputra basin sub-zone | 2(a) |
| 9. | South Brahmaputra basin sub-zone | 2(b) |
| 10. | Mahi and Sabarmati sub-zone | 3(a) |
| 11. | Lower Narmada and Tapi sub-zone | 3(b) |
| 12. | Upper Narmada and Tapi sub-zone | 3(c) |
| 13. | Mahanadi sub-zone | 3(d) |
| 14. | Upper Godavari sub-zone | 3(e) |
| 15. | Lower Godavari sub-zone | 3(f) |
| 16. | Indravati sub-zone | 3(g) |
| 17. | Krishna & Pannar sub-zone | 3(h) |
| 18. | Kaveri Basin sub-zone | 3(i) |
| 19. | Eastern Coast sub-zones | 4(a), 4(b) & 4(c) |
| 20. | West Coast region sub-zones | 5(a) & 5(b) |
| 21. | Western Himalayas zone | 7 |

# APPENDIX- 2

*(Clause 106.9.3.1)*

## TYPICAL METHOD OF DETERMINATION OF WEIGHTED MEAN DIAMETER OF PARTICLES ($d_m$)

Representative disturbed samples of bed materials shall be taken at every change of strata upto the maximum anticipated scour depth. The sampling should start from 300 mm below the existing bed. About 500 gms of each of the representative samples so collected shall be sieved by a set of standard sieves and the weight of soil retained in each sieve is taken. Theresults thereof are then tabulated. A typical test result is shown below (**Tables I & II**).

**Table - I**

| Sieve Designation | Sieve Opening (mm) | Weight of Soil Retained (gm) | Percent Retained |
|---|---|---|---|
| 5.60 mm | 5.60 | 0 | 0 |
| 4.00 mm | 4.00 | 0 | 0 |
| 2.80 mm | 2.80 | 16.90 | 4.03 |
| 1.00 mm | 1.00 | 76.50 | 18.24 |
| 425 micron | 0.425 | 79.20 | 18.88 |
| 180 micron | 0.180 | 150.40 | 35.86 |
| 75 micron | 0.75 | 41.00 | 9.78 |
| Pan | - | 55.40 | 13.21 |
| | | Total 419.40 | |

**Table - II**

| Seive No. (1) | Average Size (mm) (2) | Percentage of Weight Retained (3) | Column (2) x Column (3) (4) |
|---|---|---|---|
| 4.00 to 2.80 mm | 3.40 | 4.03 | 13.70 |
| 2.80 to 1.00 mm | 1.90 | 18.24 | 34.66 |
| 1.00 to 425 micron | 0.712 | 18.88 | 13.44 |
| 425 to 180 micron | 0.302 | 35.86 | 10.83 |
| 180 to 75 micron | 0.127 | 9.78 | 1.24 |
| 75 micron & below | 0.0375 | 13.21 | 0.495 |
| | | Total | 74.365 |

Weighted mean diameter $d_m = \frac{74.365}{100}$

$= 0.74365$

Say 0.74 mm

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the Code/Guidelines/ Manual etc. from the date specified therein)

Price: ₹800/-
(Plus Packing & Postage)